HYDRO ENVIRONMENTAL SERVICES

22 Lower Main St
Dungarvan
Co.Waterford
Ireland

tel: +353 (0)58 44122
fax: +353 (0)58 44244
email: info@hydroenvironmental.ie
web: www.hydroenvironmental.ie

DRUMCLIFF BURIAL GROUNDS, ENNIS, CO. CLARE

Hydrological and Hydrogeological Assessment for the Proposed Extension to Drumcliff Burial Grounds, Ennis, Co. Clare

FINAL REPORT

Prepared for:

CLARE COUNTY COUNCIL

Prepared by:

HYDRO-ENVIRONMENTAL SERVICES

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Author(s):	**Michael Gill** **Adam Keegan** **Jenny Law**
Signed:	 **Michael Gill B.A., B.A.I., M.Sc., MIEI** **Managing Director – Hydro-Environmental Services**

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TABLE OF CONTENTS

FIGURES (IN TEXT)

TABLES (IN TEXT)

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

Hydro-Environmental Services was requested by Clare County Council (CCC), to prepare a Hydrological and Hydrogeological Assessment Report for the development of an extension to the existing Burial Ground at Drumcliff, Ennis, Co Clare. A site location map is shown below in **Figure A**.

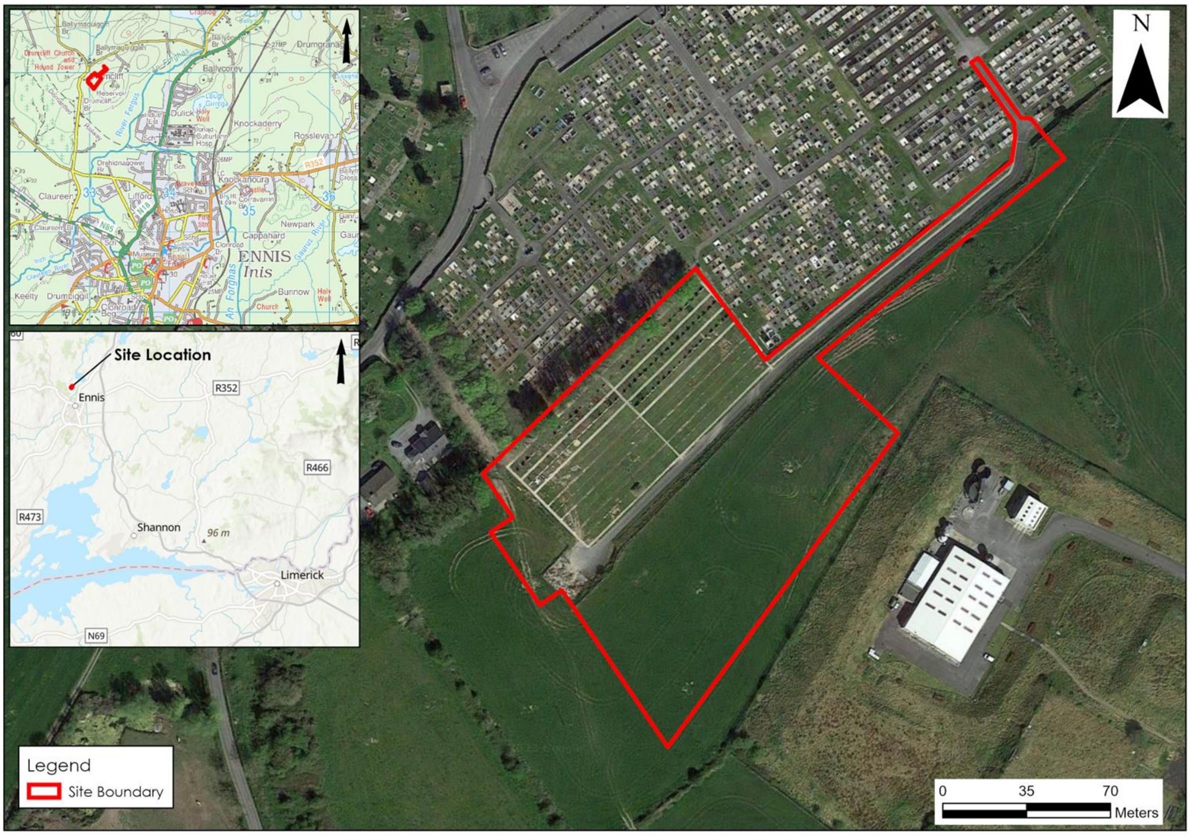


Figure A: Site Location Map

1.2 STATEMENT OF AUTHORITY

Hydro-Environmental Services (HES) are a specialist geological, hydrological, hydrogeological, and environmental practice that delivers a range of water and environmental management consultancy services to the private and public sectors across Ireland and Northern Ireland. HES was established in 2005, and our office is located in Dungarvan, County Waterford.

Our core areas of expertise and experience include geology, hydrology, hydrogeology, and karst hydrogeology and wind farm drainage design and management. We routinely complete impact assessments for hydrology and hydrogeology for a large variety of project types including quarries, wind farm and grid connection developments, and commercial and housing developments.

This report was prepared by Michael Gill, Adam Keegan and Jenny Law.

Michael Gill P.Geo (BA, BAI, Dip Geol., MSc, MIEI) is an Environmental Engineer and Hydrogeologist with over 22 years environmental consultancy experience in Ireland. Michael has completed numerous hydrological and hydrogeological impact assessments of wind farms and renewable projects in Ireland. He has substantial experience in karst hydrogeology and also in surface water drainage design and SUDs design and surface water/groundwater interactions. Michael has worked on karst related projects, including Wind Farms, quarries, large industrial developments and SHD's in South and Mid Galway, Roscommon, Tipperary, Laois, Kilkenny, Limerick, Clare, Cork and Waterford.

Adam Keegan (BSc, MSc) is a hydrogeologist with five years of experience in the environmental sector in Ireland. Adam has been involved in Environmental Impact Assessment Reports (EIARs) for numerous projects including wind farms, grid connections, quarries and small housing developments. Adam holds an MSc in Hydrogeology and Water Resource Management. Adam has worked on Environmental Impact assessments and hydrogeological assessments within karst environments including housing developments, wind farms and quarries, and has experience in groundwater exploration and development within karst environments within Tipperary, Wexford, Kilkenny and Galway.

Jenny Law (BSc, MSc) is an environmental geoscientist holding a first honours degree in applied environmental geosciences from the University College Cork. Jenny has assisted in the preparation of the land, soils and geology and hydrology chapters for various environmental impact assessment reports, hydrological impact assessments, Water Framework Directive Assessment reports and Flood Risk Assessment reports for a variety of projects including wind farm developments and strategic housing developments.

In order to assess the hydrological and hydrogeological environment at Drumcliff Burial Grounds, Ennis, Co. Clare, we have undertaken the following scope:

1. Hydrological and hydrogeological desk study (**Table A**);
2. Review of available site investigation data;
3. Site walkover and drainage mapping; and,
4. Hydrological & Hydrogeological Assessment Report.

2 HYDROLOGICAL AND HYDROGEOLOGICAL CHARACTERISATION

2.1 INTRODUCTION

A desk study of the site and the surrounding area was completed in advance of undertaking the walkover survey. This involved review and collation of all relevant geological, hydrological and hydrogeological data for the area. This included consultation and review of the following data sources:

- Environmental Protection Agency Database (**www.epa.ie**);
- Geological Survey of Ireland - Groundwater Database (**www.gsi.ie**);
- National Parks & Wildlife Services Public Map Viewer (**www.npws.ie**);
- Water Framework Directive "catchments" Map Viewer (**www.catchments.ie**);
- Geological Survey of Ireland - Bedrock Geology 1:100,000 scale (**www.gsi.ie**);
- Geological Survey of Ireland – Groundwater Body Initial Characterisation Reports for Ennis GWB; and,
- Ground Investigations Ireland – Drumcliff Burial Grounds Ground Investigation Report (April 2022).

2.2 DESK STUDY

A summary of baseline environmental conditions at the site and surrounding area is presented in **Table A**. Further detailed information on hydrology, hydrogeology, and designated sites are presented below in Sections 2.3, 2.4, and 2.5.

Table A: Environmental conditions at the site and in the surrounding area

Physical Feature	Details
Site Description	The proposed development site is currently greenfield, and is located south and adjacent to the existing Drumcliff burial ground. The site is accessed from the Drumcliff road which runs adjacent to the western boundary of the existing Drummcliff burial ground. Corine landuse data (2018) for the proposed development site and the majority of the surrounding lands are mapped as agricultural pastures. Ennis Water Treatment Works is situated directly south (and up-gradient) of the proposed development site. There are several isolated residential dwellings situated along the Drumcliff road north of the proposed development site.
Topography	Topography at the site is generally lowest along the northern border, adjacent to the existing burial grounds and increases towards the south. Elevations range from approximately 17 – 29mOD. Further south of the site, elevations reach ~40mOD at the Water Treatment Works, before the land falls again sloping towards the River Fergus.
Historical Mapping	Historic 25" and 6" Ordnance Survey mapping was consulted for indications of the environmental condition of this area. There are no mapped watercourses or springs, or areas liable to flooding mapped within the site shown on either of the historical mapping datasets. North of the site, on the opposite side of the Drumcliff road, the 6" mapping shows an area labelled as "liable to flooding" ~100m from the Poulacorry River.
Mapped soils/subsoils	Soils within the site are mapped by the EPA (www.epa.ie) as well-drained fine loamy drift with limestones that have the association name of "Faoldroim" according to the SIS National Soils map. Subsoils within the site are mapped by the GSI (www.gsi.ie) as Till derived from Devonian sandstones. In the wider surrounding area, subsoils are generally mapped as a mixture of till derived from limestones and Karstified Bedrock Outcrop or Subcrop with some areas of Lake Marl mapped to the north and

	Urban areas mapped to the south near Ennis town. Alluvium soils are mapped along the Fergus River (EPA Code: 27F01) southeast of the site and along the Drumcliff 27 (EPA Code: 27D20) 1st order stream to the north of the site.
Bedrock Geology	The site is underlain by limestone bedrock of the Burren Formation, which comprises pale grey clean skeletal limestone from the Dinantian (Lower Carboniferous period) (www.gsi.ie). There are no mapped faults on the site. The closest mapped fault is located ~6.3km south of the site. The GSI does not record the presence of any bedrock outcrop at the site.
WFD Status & Risk	Surface Water Refer to Section 2.3 below. Groundwater The Ennis GWB (IE_SH_G_160) achieved Good status under the most recent WFD cycle (2016-2021). The groundwater body risk rating is under review for the Ennis GWB.
Mapped karst features	There are no mapped karst features within the site. Approximately 200m north of the site, a swallow hole is mapped, with traced underground connections with a Drumcliff spring located approximately 1.3km further south.
Mapped water wells	The site is mapped within the Drumcliff Springs Public Water Supply (PWS)'s Inner protection zone. There is 1 no. well mapped to the very west of the site with a locational accuracy of 1km. The borehole is used for agriculture and domestic purposes and has a yield of 1.4 cubic metres per day.
Flooding	Flood zones are mapped using (www.floodinfo.ie). The CFRAM (Coastal Flood Risk Assessment and Management) River and Coastal Flood extents are mapped approximately 240m southeast of the site along the river Fergus with low, medium and high probabilities for the present-day, mid-range future and high-end future scenarios. Approximately 210m north of the site there is modelled National Indicative Fluvial Mapped River extents mapped along the Drumcliff 1st order stream which continues along the Shallee and Fergus rivers and Ballyallia Lough with low to medium probabilities. There are no past flood events mapped on the site. The nearest mapped past flood event is a single flood event approximately 1.1km southeast from the site along the River Fergus at Aughanteeroe Bridge, Ennis in December 1959. The GSI winter 2015/2016 surface water flooding maps an area approximately 200m northeast of the site. In 25" and 6" historic maps this area is also identified as "Kinnally's Holes" and is labelled as an area "Liable to floods" in 25" historic mapping. The River Fergus to the southeast of the site is also mapped as a GSI winter 2015/2016 surface water flooding area. An area of historic groundwater flooding is mapped approximately 130m northeast of the site. Groundwater flooding probability mapping is modelled with great extents along the Drumcliff River, north of the site and continues along the Shallee and River Fergus and into Ballyallia Lough with low, medium and high probabilities.

Downstream surface water abstractions	The river Fergus_070, southeast of the site is listed under Article 7 – Abstraction for Drinking Water.
Designated Sites	Refer to Section 2.5 below.

2.3 HYDROLOGY

The site is situated within the Fergus_SC_030 sub-catchment, within the Lower Shannon Estuary North catchment, Hydrometric Area no. 27 (www.epa.ie).

The Drumcliff 27 (EPA Code: 27D20) 1st order stream is approximately 230m north of the site, immediately north of the older "Calvary section" of the existing burial grounds on the northern side of the Drumcliff road. The Drumcliff stream continues northeast and feeds into the Poulacorry River (referred to by EPA as Shallee 27 (EPA Code: 27S01), which in turn feeds into the River Fergus further northeast. The River Fergus flows into Ballyallia Lough approximately 1km northeast of the site. The Fergus River exits the lake and flows south, approximately 600m southeast of the site.

The Drumcliff 27 (27D20) stream, Poulacorry River (Shallee 27) and the Firver Fergus waterbodies near the site are all mapped within the Fergus_050 section of the River Fergus. The Fergus_050 waterbody achieved Good status under the WFD Assessment (2016-2021). The Fergus River flows into the Ballyalia Lake ~1km east of the site. The Ballyalia Lake achieved Good Status under the WFD Assessment Round (2016-2021). Both the Fergus_050 waterbody and Ballyalia Lake are considered not at risk under the WFD Assessment Round (2016-2021).

There are no surface water features within the site and therefore there are no direct hydrological connections or pathways to downstream surface waterbodies and designated sites. Local surface water features are shown in **Figure B**.

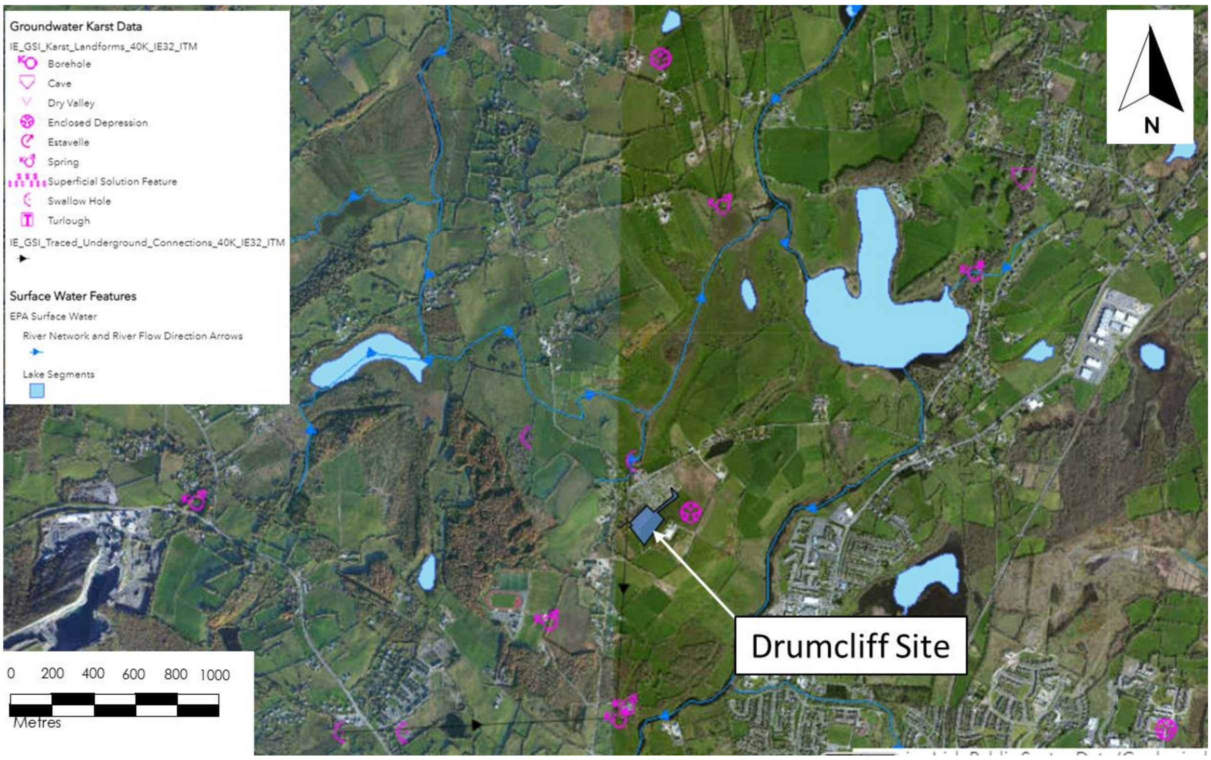


Figure B: Local Surface Watercourses with Mapped Karst Features

The OSI historical mapping shows no record of karst features within the proposed development site. Historical mapping does identify karst features in the surrounding areas, including “Poulacorey” swallow hole north of the site and “Kinnally’s Holes” to the east of the site, additionally labelled as an area liable to flooding in 25” historic mapping.

2.4 SITE HYDROGEOLOGY

2.4.1 Geology and Aquifer Classification

The site is underlain by the Burren Formation, which comprises pale grey clean skeletal limestone from the Dinantian (Lower Carboniferous period) (www.gsi.ie). A local geology map is included in **Figure C**.

This proposed development site is located within a karstified Limestone Aquifer (**Figure D**), while there are no karst features mapped within the site, karst features including swallow holes, springs, caves, and enclosed depressions are present within the wider Ennis area (refer to **Figure D**).

Groundwater within the site will follow the topography and flow downgradient, in a northern direction. No groundwater was encountered during the trial pitting site investigations.

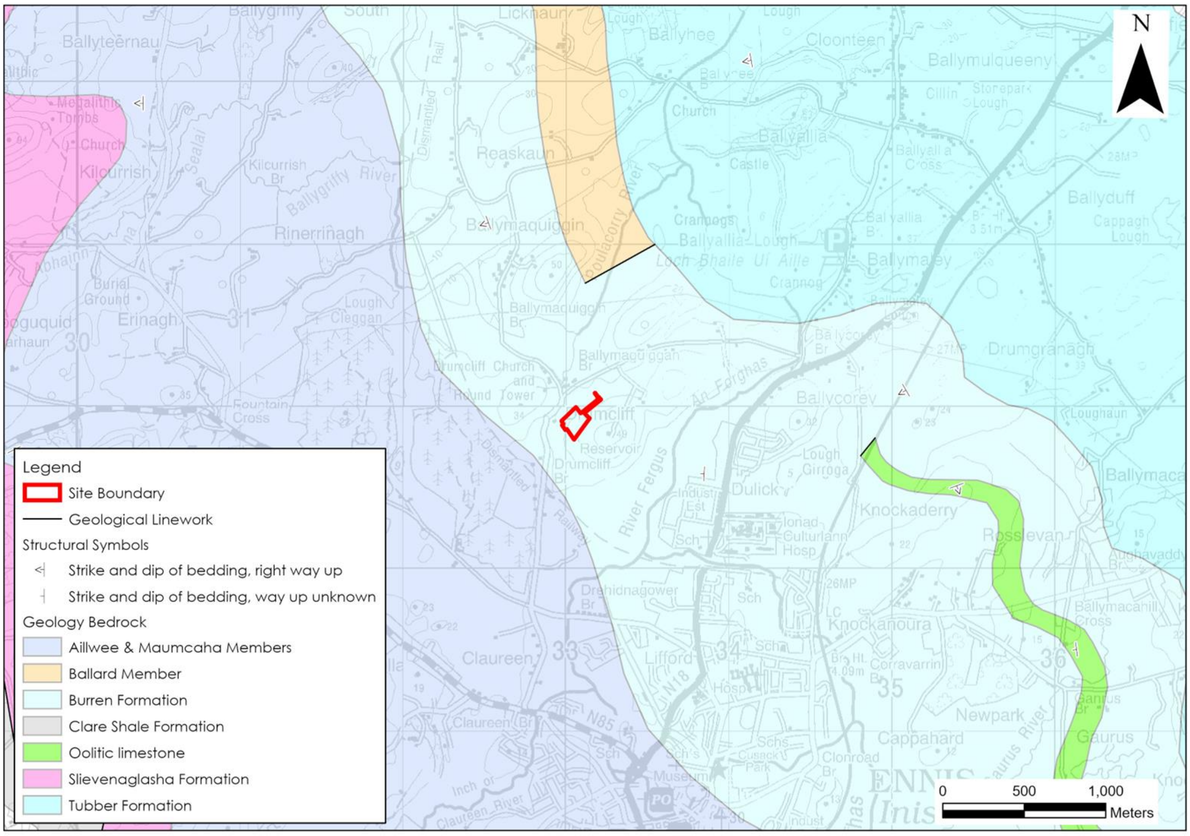


Figure C: Local Geology Map

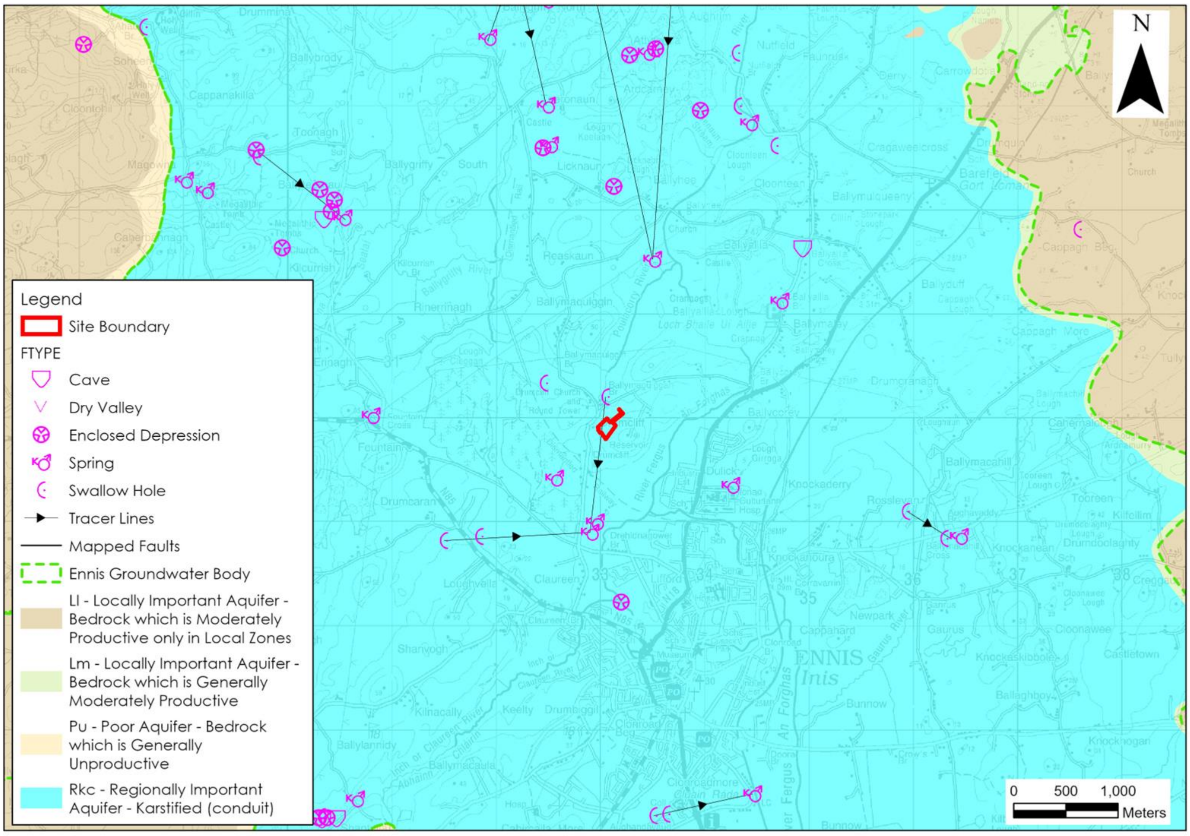


Figure D: Groundwater Body Map

2.4.2 Groundwater Vulnerability

Groundwater Vulnerability within the site is mapped as Moderate, with a small section to the north mapped as High. The Groundwater vulnerability mapping generally increases in vulnerability to the north, as the subsoil is inferred to decrease in thickness to the north.

The quaternary subsoil is mapped as tills derived from Devonian sandstones which typically form the drumlins of high ground in the area. In the wider surrounding areas, subsequent erosion has left limestone tills and Kartsified bedrock outcrop or subcrop in the lower elevation areas that surround the site.

Groundwater Protection Scheme report for the Drumcliff PWS (Deakin and Daly, 2000), describes the Devonian sandstone tills that are mapped to underly the site as having a variable matrix which usually has a relatively high percentage of sand with significant clay. This is attributed to the nature of the Old Red Sandstone bedrock which comprises both coarse red sandstones and interbedded shales. The sandstones break down into sand sized particles while the shales give rise to silt and clay-sized particles. The tills can be either clay rich, well consolidated, firm to stiff deposits which have been laid down under the ice as lodgement tills; or much looser, more sandy deposits which may have been laid down as the ice melted. In some places, the more sandy deposits are found overlying the clayey tills.

The subsoil thickness and its relationship to groundwater vulnerability at the site are discussed further in Sections 2.6 and 2.6.2, referring to the site-specific ground investigations carried out at the proposed development site.

The classification system for Groundwater Vulnerability as employed by the GSI within the vulnerability mapping is shown below in **Plate A**.

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.

Plate A: Groundwater Vulnerability Classification Scheme

A local groundwater vulnerability map is shown in **Figure E**.

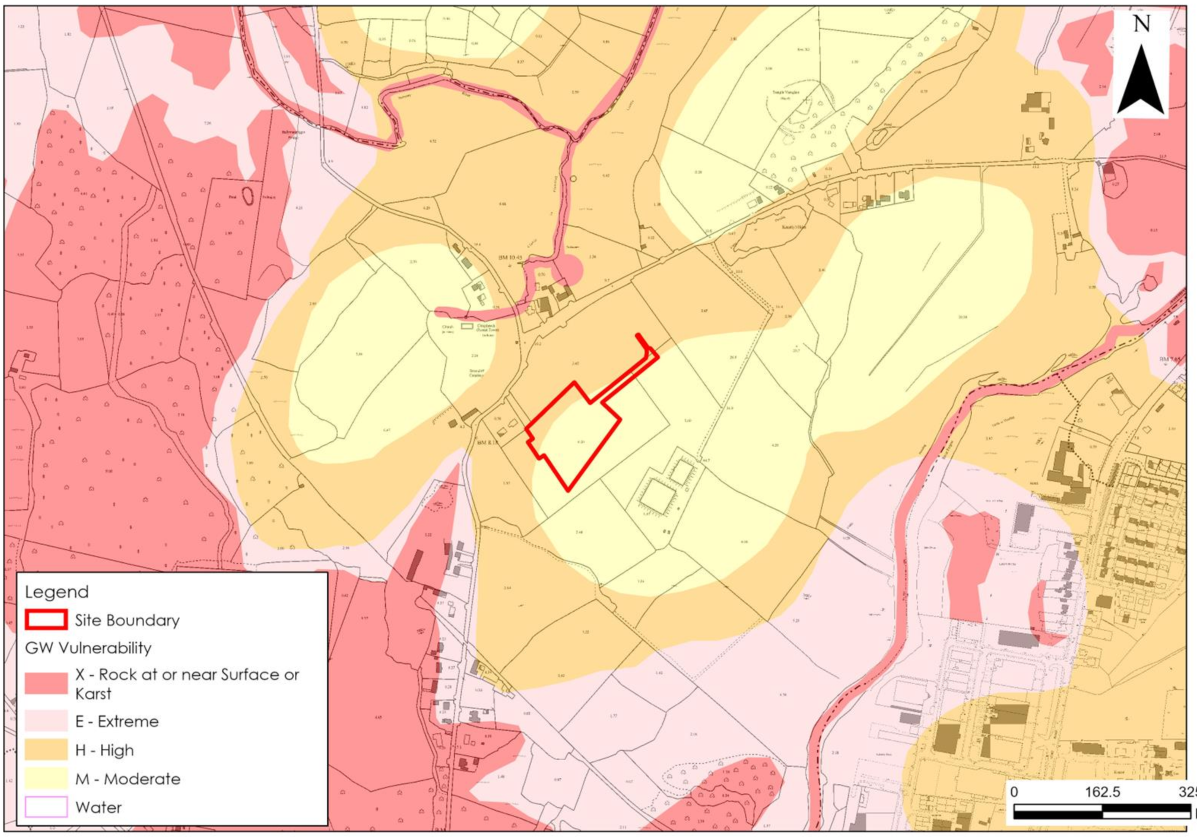


Figure E: Groundwater Vulnerability Map

2.4.3 Groundwater WFD Status

The Ennis GWB (IE_SH_G_160) achieved Good status under the most recent WFD Assessment Round (2016-2021). The Ennis GWB has achieved Good status through all cycles of the WFD Assessment process since 2007.

The groundwater body risk rating is under review for the Ennis GWB.

2.4.4 Water Resources

The Drumcliff Spring PWS is situated ~1km southwest of the proposed development site. The Drumcliff Spring PWS supplies ~ 12,000 m^3/day to Ennis and the surrounding area.

The nearest mapped karst feature to the site is the Poulacorey swallow hole, located ~200m north of the existing burial grounds, and ~250m north of the proposed development site. A dye tracer test was performed at the Poulacorey swallow hole, with a positive detection at Drumcliff Springs, indicating a direct groundwater connection from this swallow hole to the Drumcliff Spring.

The existing Drumcliff cemetery and the proposed extension site are located within the Source Protection Zone for the Drumcliff Spring PWS.

Consultation with respect to the proposed development has been made with Uisce Éireann.

2.5 DESIGNATED SITES

Ballyallia Lough SPA (Site code: 004041), Ballyallia Lake pNHA and SAC (Site Code: 000014) are situated approximately 200m north of the site. The southern extent of the Ballyalia Lake pNHA and SAC includes the Poulacorry River and its banks.

Outflowing from Ballyallia Lough is the River Fergus which is mapped within the Lower River Shannon SAC (Site Code: 002165), ~600m southeast of the site.

Further downstream, at Clarecastle, approximately 6km south of the site is the Fergus Estuary and Inner Shannon, North Shore pNHA (Site Code: 002048) and the River Shannon and River Fergus Estuaries SPA (Site Code: 004077).

2.6 SITE GEOLOGY

2.6.1 Intrusive Site Investigation

A site investigation has been completed by Ground Investigations Ireland (GII) (April 2022)[1]. The scope of the work undertaken for this project included the following:

- Site walkover to observe existing ground conditions;
- Excavate 5 No. Trial Pits to a maximum depth of 1.90mbgl; and,
- Perform 5 No. Soakaways to determine a soil infiltration value to BRE digest 365.

A full copy of the site investigation report is attached as **Appendix I** and a map showing the locations of the site investigations is shown in **Figure F**. A summary of the site investigation data for the site is presented as follows:

- Topsoil was encountered in all the exploratory holes and was present at a maximum depth of 0.25m BGL;
- Made ground deposits were only encountered in IF1 between 0.15 - 0.70m and were described as grey very clayey sandy sub-rounded to rounded fine to coarse Gravel; and,
- Cohesive deposits were encountered beneath the Made Ground and were described typically as reddish brown slightly sandy gravelly CLAY with occasional cobbles or grey/brown slightly sandy gravelly CLAY. The secondary sand and gravel constituents varied across the site and with depth, with granular lenses occasionally present in the

[1] *Drumcliff Burial Grounds Clare Co. Council, Ground Investigation Report dated April 202, Project No 11545-03-22, Ground Investigations Ireland*

glacial till matrix. These deposits had some, occasional or frequent cobble and boulder content. The top of the cohesive deposits was logged as 0.7m in IF1 and between 0.15 – 0.25m in IF2-IF5. The cohesive deposits were logged to the base of each trial pit, which varied in depth between 1.7 – 1.9m.

Groundwater

No groundwater was noted during the investigation however the exploratory holes did not remain open for sufficiently long periods of time to establish the hydrogeological regime and groundwater levels would be expected to vary with the time of year, rainfall, nearby construction and other factors. Surface water was present in close proximity to IF3, likely due to the impermeable nature of the Topsoil in that area.

Soakaway Design

Infiltration rates of f=6.257 x 10^{-6} m/s, f=4.685 x 10^{-6} m/s, f=4.446 x 10^{-6} m/s and 2.771 x 10^{-6} m/s respectively were calculated for the soakaway locations SA01, SA03, SA04 and SA05. At the location of SA02 the water level dropped too slowly to allow calculation of the soil infiltration rate (indicating very low permeability).

Figure F: Site Investigation Locations

2.6.2 Geophysics

Minerex Geophysics LTD. (MGX) was commissioned to carry out a geophysical survey of the proposed development at Drumcliff, Co. Clare. The survey consisted of EM31 ground conductivity, 2D-Resistivity and seismic refraction (p-wave) investigations.

The main objectives of the geophysical survey were:

- To determine the ground conditions underlying the site;
- To determine the depth to rock and the overburden thickness;
- To estimate the strength or stiffness or compaction of overburden materials and the bedrock quality;

- To determine the type of overburden and bedrock;
- To detect possible karstified zones within the bedrock or karst features; and,
- To identify potential groundwater flow paths under the site.

The MGX report is attached as **Appendix II**.

<u>EM31 Conductivity Survey</u>
The EM31 ground conductivity survey was carried out over the area indicated in Map 1 (**Appendix II**) on lines nominally 10m apart. EM31 ground conductivity determines the bulk conductivity of the subsurface over a typical depth between 0-6mbgl.

The natural conductivity levels are very uniform across the survey area ranging from 5 to 9 mS/m. This indicates a boulder clay overburden across the survey area with little variation in composition.

The resistivities cover a range typical for materials from clay rich overburden (low resistivities) to fresh strong unweathered bedrock (high resistivities). The ranges have been taken into the consideration for the interpretation. The overburden on this site is dominated by medium resistivity values (125 - 500 Ohmm) which typically indicate a boulder clay. High resistivities at depth (>500 Ohmm) indicate a clean limestone bedrock.

<u>Resistivity Survey</u>
2D-Resistivity lines were surveyed with electrode spacing of 3m, up to 64 electrodes per set-up. The penetration depth of a resistivity set-up increases towards the centre where it reaches depths of over 15m. 2D-Resistivity has previously proven zones of anomalous or karstified rock with lateral extents of 5m and more.

The modelled seismic data has created the following layered ground model:

1. Layer 1: has a thickness of up to 2m and seismic velocities of 200 - 300m/s. This overburden would be soil with a soft or loose stiffness or compaction.
2. Layer 2: was modelled with a velocity of 1600m/s and reaches a depth between 2.5 and 5.5m. The velocity indicates overburden material with very stiff strength or compaction.
3. Layer 3: velocities of 2400m/s indicate predominantly overburden with hard strength or compaction. The thickness or depth varies between 4 and 9.5 m.
4. Layer 4: Strong rock is indicated by seismic velocities of 4500m/s and the top of this strong rock varied between 8.5 and 13.5m.

<u>Overall Conclusion</u>
The geophysical surveys carried out for the Drumcliff Cemetery extension consisted of EM31 Ground Conductivity, 2D-Resistivity and seismic refraction surveying.

- At all locations, there was a strong correlation between all three geophysical survey methods.
- The EM31 Ground Conductivity data shows a consistent boulder clay overburden throughout the survey area.
- The 2D-Resistivity data shows thick boulder clay across all three lines. High resistivities at depth indicate a clean limestone bedrock.
- The seismic refraction data were modelled with a total of four layers (as discussed above).
- The data is very uniform across the survey area with only small variations in the overburden composition and rock depth across the survey area.
- The thick layer of clay dominated boulder clay would cause low groundwater permeability.
- Within the rock layer, there is no indication of karstified limestone. The thick overlying highly consolidated glacial till will provide good protection from any underlying karstified limestone that may be present deeper than the survey depth.

The presence of 8.5-13.5m of overburden puts the site within the Low-Moderate Risk Rating for groundwater vulnerability (as outlined in Section 2.4.2, **Plate A**). A subsoil thickness of >10m is the threshold for Low vulnerability, which is likely the average thickness across the site based on the geophysical cross sections, and the supporting data from the shallower trial pits.

3 DEVELOPMENT DESCRIPTION

3.1 DEVELOPMENT DESCRIPTION

The proposed development comprises improvement works to St Brigid's Section E and the development of an extension to the existing Burial Ground at Drumcliff, Ennis, Co Clare.

The development will include:

1) An addition of circa 350 double plots including provision for ash plots.
2) Access road improvements including lay-bys, turning circle and traffic calming measures. 3) Parking; 23 standard spaces, 6 Wheelchair accessible spaces.
3) Footpaths.
4) Drainage.
5) Planting and landscaping including Columbarium and Reflectance Garden.
6) Associated Site Works.

The proposed site layout is shown as **Figure** below**.**

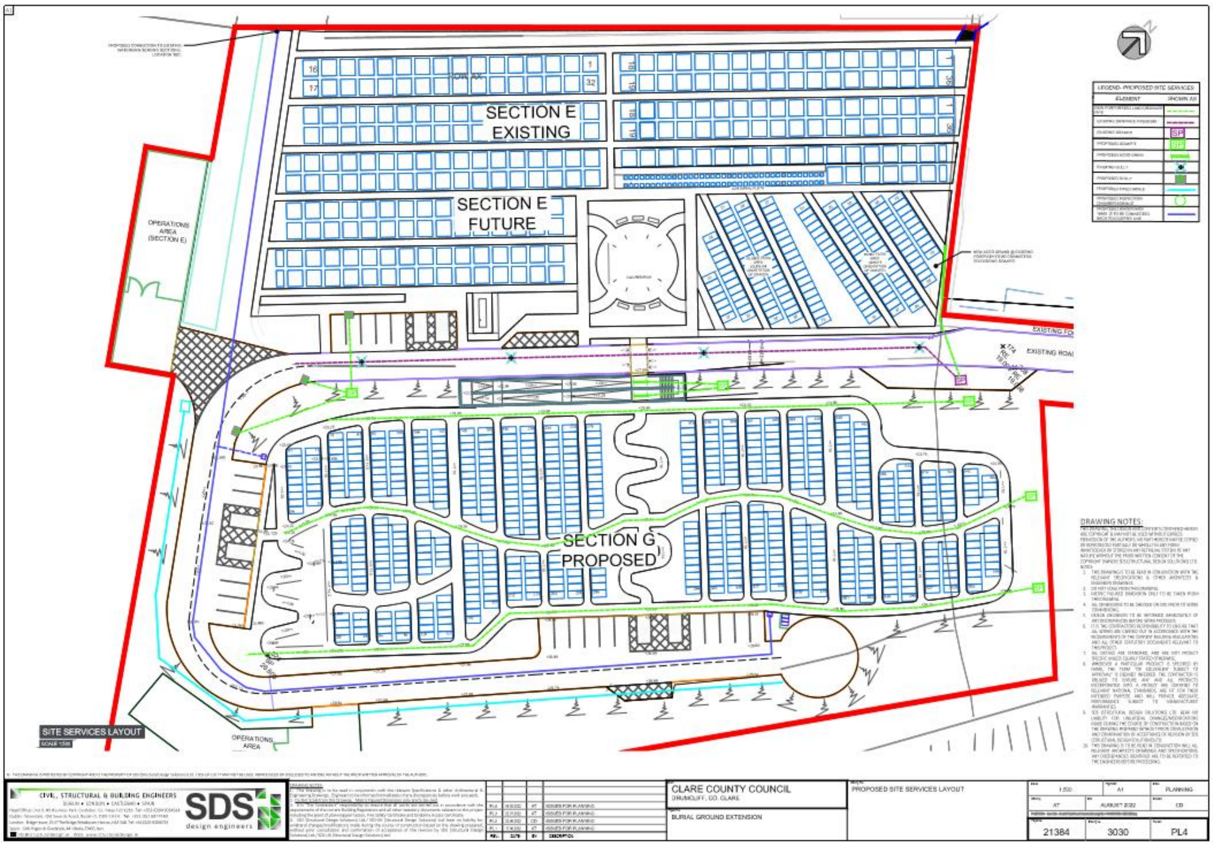


Figure F: Proposed Site Layout

3.2 LANDSCAPE PROPOSALS

The proposed development has several open space areas. Due to the slope and the proposed site levels as shown in **Figure G**, areas are dedicated to open green space. The central space will be paved and maintained as a central area for social meeting. A network of pathways will extend from the public path to provide circulation routes around and through this space to connect each open space area. Seating areas will be provided adjacent to the pathways in locations that provide views of the surrounding area.

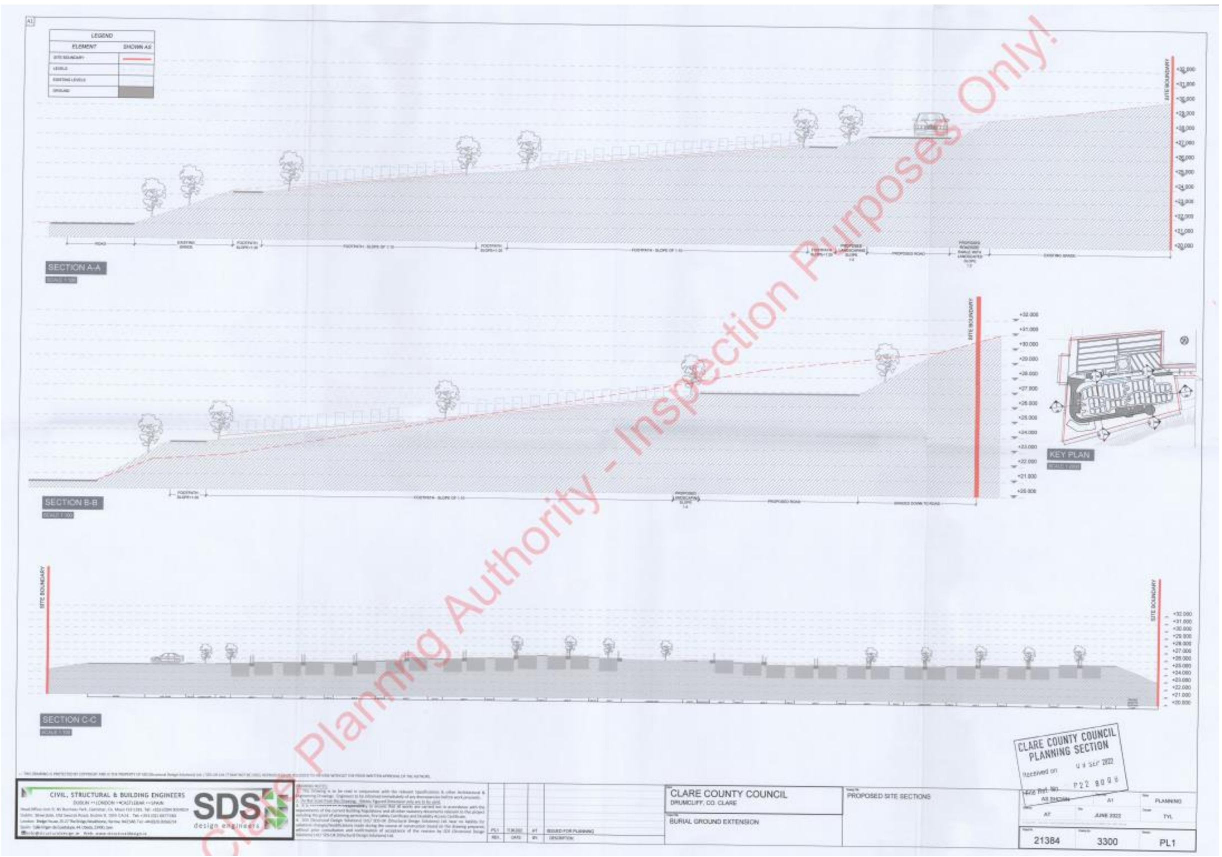


Figure G: Site Cross Sections

3.3 PROPOSED DRAINAGE DESIGN

A detailed drainage design plan has been prepared for the proposed development. The drainage design has taken into account the sloping nature of the site, with drainage features running with the existing ground contours to ensure that all surface waters arising at the site are captured within the drainage system, with no direct unattenuated discharge of surface water from the proposed development site.

The design of the drainage system incorporates the following measures:

- Surface water falling on green (grave) areas will infiltrate into green areas. Perforated pipes running below paths across the slope of the land, will collect heavy flows and divert to soak pits at the northeastern boundary of the Section G extension.
- Footpaths will be sloped toward adjacent green areas to allow for infiltration. Surface water from footpaths, which does not directly infiltrate to ground, will be collected within the perforated drainage pipes.
- Surface water from new roadway will generally be served by an open swale along the roadway. A soak pit area will be provided at the lowest point of the swale run to accommodate any heavy flows of surface water than is not absorbed by the swale itself.

- New gullies serving existing roadway/proposed roadway junction area are served by a soak pit.
- Main Pedestrian Access Ramp and stairs with non-porous finish to be accommodated by soak pit.
- Acco drain to be added to Section E area is to be served by an existing soak pit.

4 HYDROLOGICAL AND HYDROGEOLOGICAL RISK ASSESSMENT

4.1 CONCEPTUAL SITE MODEL AND RISK ASSESSMENT

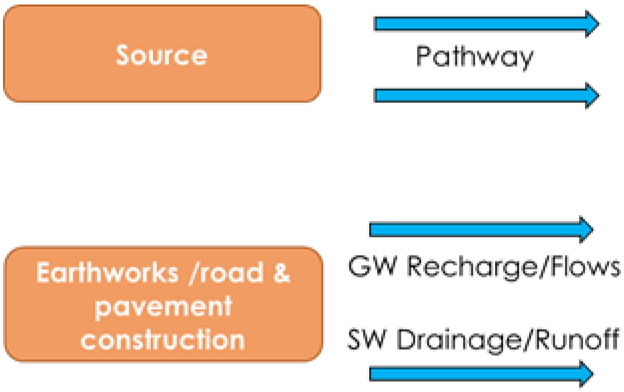
Based on information contained within the previous sections, including the desk study and site-specific site data (trial pitting, soakaway tests and geophysical survey), a conceptual site model (CSM) has been developed for the proposed development site, and the CSM is outlined as follows:

- Topography within the site ranges from 17 – 29mOD, with land sloping steeply to the north;
- The soils overlying the site have been logged within 5 no. trial pits and are described as brown, sandy gravelly Topsoil. Subsoils are logged as reddish brown slightly sandy gravelly CLAY with occasional cobbles or grey/brown slightly sandy gravelly CLAY. Trial pits were excavated to 1.7-1.9m and did not encounter bedrock or groundwater;
- Infiltration rates within the soil/subsoil have been determined as ranging between $2.7x10^{-6}$ and $6.25x10^{-6}$ m/s, indicating generally low-moderate permeability across the site;
- The geophysical survey data has been interpreted as indicating subsoils consisting of a thick layer of boulder clay between 8.5 - 13.5m deep, with hard strength or compaction within the deepest interpreted subsoil layer;
- The depth to bedrock has been interpreted as ranging between 8.5-13.5mbgl from the geophysical survey. The data on the bedrock layer indicates a clean Limestone bedrock with no identified karst features or anomalies;
- Broadly, the site can be interpreted as being located on a low permeability drumlin feature, with a high degree of aquifer protection due to the underlying thick subsoil deposits. These subsoils would have been deposited towards the end of the last glacial maxima. The low-moderate permeability subsoils may have provided protection for the underlying Limestone bedrock from dissolution/karstification;
- Due to the low/moderate permeability of the soil and subsoil and the inferred low permeability of the bedrock aquifer (from the geophysical survey), the primary pathway for rainfall is via surface water pathways (runoff) rather than via groundwater pathways. The low/moderate permeability of the subsoils ($2.7x10^{-6}$ – $6.5x10^{-6}$ m/s) will inhibit significant volumes of groundwater recharge from occurring within the site;
- Groundwater recharge will generally be low and groundwater and surface water flows will follow the topography, flowing to the north; and,
- With a carefully designed drainage system (as outlined in Section 3.3) surface water drainage can be managed within the proposed development site.

4.2 OVERVIEW OF THE ENVIRONMENTAL ASSESSMENT PROCESS

The environmental assessment process requires the identification of all potential sources, pathways and receptors of contamination and identifying plausible combinations of these three components. Potentially significant pollutant linkages can then be qualitatively or quantitatively assessed to identify potential risks.

The conventional source-pathway-target model, as seen below, was applied to assess potential impacts on downstream environmental receptors (see below, bottom as an example) as a result of the proposed development.



4.3 CONSTRUCTION PHASE IMPACT ASSESSMENT

4.3.1 Earthworks and Drainage Network Construction

Construction phase activities including site levelling and excavations for access roads, pathways, carparking areas, drainage channels and soakaway pits will require earthworks resulting in the removal of vegetation cover where present and excavation of soil and subsoils. The main risk will be from surface water runoff from bare soil and spoil storage areas during construction works.

These activities can result in the release of suspended solids in surface water runoff and could result in an increase in the suspended sediment load, resulting in increased turbidity. This could affect the water quality of downstream water bodies such as the Poulacorry River and River Fergus. An increase in suspended sediment loads could also impact on the status of the waterbodies under the Water Framework Directive. The Fergus_050 waterbody is currently assigned "Good" status under the WFD 2016-2021.

Pathways: Drainage and surface water runoff.

Receptors:

- ➢ Down-gradient rivers including the River Fergus and the WFD objectives associated maintain the WFD quality *i.e.* Good status.
- ➢ Ballyalia Lake, downgradient of the River Fergus and the WFD objectives associated maintain the WFD quality *i.e* Good status.
- ➢ Topographically down-gradient designated sites *i.e.* Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.
- ➢ Poulacorey karst feature (and associated link with Drumcliff Spring PWS).

Pre-Controls/Design Potential Impact:

- ➢ Negative, indirect, slight, short-term, potential impact on downstream surface water quality in the River Fergus and the associated WFD objectives;
- ➢ Negative, indirect, negligible, short-term, potential impact on Ballyalia Lake and associated designated sites - Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA;
- ➢ Negative, indirect, slight, short-term, unlikely impact on Poulacorey karst feature and Drumcliff Spring PWS.

Drainage Control Measures:

Management of surface water runoff and subsequent treatment before release off-site will be undertaken during construction work as follows:

- 2 lines of silt fencing will be constructed along the northern boundary of the site during construction;

- All stockpiles will be damped down or covered in a sheet of polythene, as required, which will prevent the creation of nuisance dust, and will also prevent sediment runoff in times of heavy precipitation; and,
- Restricting construction to within well marked areas, adherence to the non-carrying out of construction after or during heavy rainfall.

Post-Controls/Design Potential Impact:

- Negative, indirect, imperceptible, short-term, unlikely impact on downstream surface water quality in the River Fergus and the associated WFD objectives;
- Negative, indirect, imperceptible, short-term, unlikely impact on Ballyalia Lake and associated designated sites - Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA; and,
- Negative, indirect, imperceptible, short-term, unlikely impact on Poulacorey karst feature and Drumcliff Spring PWS.

Residual Effect: The potential for the release of surface water with entrained suspended sediment to surface watercourse receptors is an identified risk within the proposed development site, as is the case on any similar construction site. Proven and effective measures to prevent the release of surface water from the proposed development site during the construction phase have been proposed above and will break the pathway between the potential source and each receptor.

The residual effect is considered to be - Negative, imperceptible, indirect, temporary, unlikely effect on the 4 no. receptors listed above.

Significance of Effects: For the reasons outlined above, and with the implementation of the listed mitigation measures, no significant effects on surface quality will occur.

4.3.2 Potential Release of Hydrocarbon

Accidental spillage during refuelling of construction plant with petroleum hydrocarbons is a significant pollution risk to groundwater, surface water and associated ecosystems, and to terrestrial ecology. The accumulation of small spills of fuels and lubricants during routine plant use can also be a pollution risk.

Pathway: Groundwater flowpaths and surface water runoff.

Receptor:

1. Down-gradient rivers including the River Fergus and the WFD objectives associated maintain the WFD quality *i.e.* Good status.
2. Ballyalia Lake, downgradient of the River Fergus and the WFD objectives associated maintain the WFD quality *i.e* Good status.
3. Topographically down-gradient designated sites *i.e.* Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.
4. Poulacorey karst feature (and associated link with Drumcliff Spring PWS).

Pre-Controls/Design Potential Impact:

- Negative, significant, indirect, short term, likely effect on surface water quality in down gradient rivers (River Fergus);

- Negative, slight, indirect, short term, unlikely effect on local groundwater quality in the underlying aquifer at the site - Ennis GWB;

- Negative, significant, indirect, short term, potential effect on surface water quality near Poulacorey karst feature; and,

- Negative, significant, indirect, short term, potential effect on nearby designated sites

Proposed Mitigation Measures:

Proposed mitigation measures are outlined as follows:

- All plant and machinery will be serviced before being mobilised to site;
- No plant maintenance will be completed on site, any broken down plant will be removed from site to be fixed;
- Refuelling will be completed in a controlled manner using drip trays at all times;
- Any fuel and chemical stores including tanks and drums will be regularly inspected for leaks and signs of damage;
- Drip trays will be used for fixed or mobile plant such as pumps and generators in order to retain oil leaks and spills;
- Only designated trained operators will be authorised to refuel plant on site;
- Procedures and contingency plans will be set up to deal with emergency accidents or spills; and,
- An emergency spill kit with an oil boom, absorbers etc. will be kept on-site for use in the event of an accidental spill.

Residual Effect: The potential for the release of hydrocarbons to groundwater and surface watercourse receptors is an identified risk within the proposed development site, as is the case on ayn similar construction site. Proven and effective measures to mitigate the risk of releases of hydrocarbons have been proposed above and will break the pathway between the potential source and each receptor.

The residual effect is considered to be - Negative, imperceptible, indirect, temporary, unlikely effect on the 4 no. receptors listed above.

Significance of Effects: For the reasons outlined above, and with the implementation of the listed mitigation measures, no significant effects on surface or groundwater quality will occur.

4.3.3 Release of Cement-Based Products

Concrete and other cement-based products (i.e. within the proposed footpaths, and pedestrian access ramp) are highly alkaline and corrosive and can have significant negative impacts on water quality. Entry of cement-based products into the site drainage system, into surface water runoff, and hence to surface watercourses or directly into watercourses represents a risk to aquatic species and habitats.

Batching of wet concrete on site and washing out of transport and placement machinery are the activities most likely to generate a risk of cement-based pollution. The pouring of concrete within forms (*i.e.* pathways) also presents a risk of cement-based pollution if carried out incorrectly.

Pathway:

Groundwater Flowpaths are not considered to be a potential pathway, the deep thickness of overburden at the site provides a significant degree of protection to the underlying aquifer and groundwater system. This depth of subsoil will act to attenuate any risks from cement-based products, such as an increase in pH, due to the timescales involved in infiltration through the subsoil.

Site drainage network/Surface Water Runoff – Surface water pathways are the main potential pathway for the transport of cement-based pollutants.

Receptors:

1. Down-gradient rivers including the River Fergus and the WFD objectives associated maintain the WFD quality *i.e.* Good status.
2. Ballyalia Lake, downgradient of the River Fergus and the WFD objectives associated maintain the WFD quality *i.e* Good status.

3. Topographically down-gradient designated sites *i.e.* Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.
4. Poulacorey karst feature (and associated link with Drumcliff Spring PWS).

Pre-Controls/Design Potential Impact:

- Negative, significant, indirect, short term, likely effect on surface water quality in down gradient rivers (River Fergus);

- Negative, slight, indirect, short term, unlikely effect on local groundwater quality in the underlying aquifer - Ennis GWB;

- Negative, significant, indirect, short term, potential effect on surface water quality near Poulacorey karst feature; and,

- Negative, slight, indirect, short term, potential effect on nearby designated sites

Negative, slight, indirect, short term, likely effect on local groundwater quality in the underlying Locally Important Aquifer. Negative, significant, indirect, short term, likely effect on surface water quality.

Proposed Mitigation Measures:

The proposed mitigation measures include:

- No batching of wet-cement products will occur on site. Ready-mixed supply of wet concrete products and where possible, emplacement of pre-cast elements, will take place;
- No washing out of any plant used in concrete transport or concreting operations will be allowed on-site;
- The contractor will use weather forecasting to plan dry days for pouring concrete; and,
- The pour site will be free of standing water, and plastic covers will be ready in case of a sudden rainfall event.

Residual Effect: The potential for the release of cement-based products to groundwater and watercourse receptors is a risk to surface water and groundwater quality. Proven and effective measures to mitigate the risk of the release of cement-based products have been proposed above and will break the pathway between the potential source and each receptor.

The residual effect is considered to be –

Negative, imperceptible, indirect, short term, unlikely impact on surface water quality in the downgradient surface water bodies (River Fergus).

Negative, imperceptible, indirect, short term, unlikely impact on groundwater quality in the underlying aquifer.

Negative, imperceptible, indirect, unlikely impact on surface water quality near the Poulacorey karst feature.

Negative, slight, indirect, unlikely impact on nearby designated sites.

Significance of Effects: For the reasons outlined above, and with the implementation of the listed mitigation measures, no significant effects on surface water quality or groundwater quality will occur.

4.4 OPERATIONAL PHASE IMPACT ASSESSMENT

4.4.1 Surface Water Quality Impacts from the Proposed Surface Water Drainage System

Surface water runoff from roads and car parking areas can potentially contain elevated levels of contaminants such as hydrocarbons and suspended solids. These contaminants have the potential to impact on local downstream groundwater and surface water quality.

Pathway:

Site drainage network/Surface Water Runoff – Surface water pathways are the main potential pathway for the transport of cement-based pollutants.

Groundwater flowpaths are not considered to be a potential pathway, the deep thickness of overburden at the site provides a significant degree of protection to the underlying aquifer and groundwater system. This depth of subsoil will act to attenuate any risks from cement-based products, such as an increase in pH, due to the timescales involved in infiltration through the subsoil.

Receptor:

- Down-gradient rivers including the River Fergus and the WFD objectives associated maintain the WFD quality *i.e.* Good status.
- Ballyalia Lake, downgradient of the River Fergus and the WFD objectives associated maintain the WFD quality *i.e* Good status.
- Topographically down-gradient designated sites *i.e.* Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.
- Poulacorey karst feature (and associated link with Drumcliff Spring PWS)

Pre-Controls/Design Potential Impact:

- Negative, indirect, slight, short-term, potential impact on downstream surface water quality in the River Fergus and the associated WFD objectives;
- Negative, indirect, negligible, short-term, potential impact on Ballyalia Lake and associated designated sites - Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA; and,
- Negative, indirect, slight, short-term, unlikely impact on Poulacorey karst feature and Drumcliff Spring PWS.

Impact Assessment:

The proposed SuDs drainage system incorporated into the engineering design of the site are common drainage systems that are used in development sites. They are proposed in accordance with the objectives outlined in the Clare County Development Plan 2017-2023. The Development plan objective for stormwater (CDP 18.8) states:

> *"It is an objective of the development plan to ensure the implementation of Sustainable Urban Drainage Systems (SuDS) and in particular, to ensure that all storm water generated in a new development is disposed of on-site or is attenuated and treated prior to discharge to an approved storm water system"*

The proposed drainage system will incorporate the following features:

- 5 no. new soakaway pits will be installed, with 2 no. soak pits installed downgradient of the new paved walkways, towards the south of the site. The remaining 3 no. soakaway pits will attenuate drainage from the northern area of the Section G proposed development site, namely the car parking area and lower access road;

- Surface water falling on green (grave) areas is infiltrated into green areas. Perforated pipes running below paths across the slope of the land, will collect heavy flows and divert to soak pits at the northeastern boundary of the Section G extension;
- Footpaths will be sloped toward adjacent green areas and surface water from footpaths will be served by the perforated drainage pipes leading to a soakaway pit.
- Surface water from new roadway will be served by an open swale along the roadway. A soak pit area will be provided at the lowest point of the swale run to accommodate any heavy flows of surface water than is not absorbed by the swale itself;
- Drainage from main pedestrian access ramp and stairs with non-porous finish will be directed towards a soak pit; and,
- New Acco drain to be added to Section E area is to be served by an existing soak pit.
- Class 1 bypass petrol interceptors are proposed within the drainage system and deliver removal efficiency rates of up to 80% for both suspended solids and hydrocarbons.

The proposed drainage system will be managed and maintained throughout the operational phase of the proposed development. The regular maintenance and cleaning of the SuDS features will ensure that adequate performance is maintained.

These standard drainage design controls will ensure the development will not give rise to any significant surface water or groundwater quality impacts at or downstream of the site.

Residual Impact: Runoff from roadways and pathways have the potential to transfer suspended solids and hydrocarbons into the groundwater and surface water environment. These contaminants have the potential to impact on local downstream groundwater and surface water quality. Proven and effective drainage measures to manage the risk of release of sediment and hydrocarbons are incorporated into the design of the proposed development and these will break the pathway between the potential sources and the receptor.

The residual effects are –

- Negative, imperceptible, indirect, medium-term, very unlikely impact on downstream surface water quality in the River Fergus and the associated WFD objectives of surface water bodies;
- Negative, indirect, imperceptible, medium-term, very unlikely impact on Ballyalia Lake and associated designated sites - Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA; and,
- Negative, imperceptible, indirect, medium-term, highly unlikely impact on Poulacorey karst feature and Drumcliff Spring PWS.

Significance of Effects: For the reasons outlined above, and with the implementation of the standard best practice drainage control measures adverse effects on the downstream surface water quality and quantity will not occur.

4.4.2 Potential Impacts from Extension to Burial Ground

The burial of human remains within the proposed Section G cemetery extension can pose a risk to groundwater quality, through the natural breakdown of human remains, leading to elevated concentrations of certain nutrients, including ammonia and nitrates.

The existing cemetery, which has been in operation for many years, does not appear to have had any effect on local groundwater quality. The average annual nitrate levels at Poulacorey swallow hole is 1.8 mg/L and it is 2.0 mg/L at Drumcliff Springs[2]. Ammonia was measured at the Drumcliff Springs (2003-2004) and the data indicates low reported values ranging between 0.01 – 0.04 mg/L.

The thick subsoils present at the site, as part of the drumlin formation have been investigated. The soils/subsoils have been logged during site investigations, with subsoils described as reddish brown slightly sandy gravelly CLAY with occasional cobbles or grey/brown slightly sandy gravelly CLAY. Soakaway tests have demonstrated a low-moderate infiltration range of 2.7×10^{-6} to 6.25×10^{-6} m/s. The geophysical interpretation describes 3 no. subsoil layers of increasing strength/compaction to a depth of 8.5-13.5m. Good, fresh Limestone is interpreted below this, with no karst anomalies identified below the proposed extension site.

Groundwater inflows were not recorded during any of the trial pit investigations, and as such the 1m unsaturated zone beneath the base of a grave site is expected to remain throughout the year.

The ability of the proposed development site to impact on groundwater quality is limited due to the site's quaternary geology, which overlies the limestone aquifer system. This thick layer of subsoils, with low-moderate infiltration rates, provides an adequate buffer to the underlying aquifer.

Pathway: Groundwater Flowpaths, groundwater infiltration through subsoils. Groundwater baseflow to nearby downgradient surface water bodies (this is included as a pathway but in reality, the transit times for groundwater base flow to any surface water body will be very slow due to the site geology, any potential sources will likely be attenuated by dilution/diffusion before reaching a surface water body).

Receptor:

- Poulacorey karst feature (and associated link with Drumcliff Spring PWS);
- Underlying groundwater aquifer (Ennis GWB) and the WFD objectives associated with maintain the WFD quality status, i.e. Good quality;
- Down-gradient rivers including the River Fergus and the WFD objectives associated maintain the WFD quality, *i.e.* Good status;
- Ballyalia Lake, downgradient of the River Fergus and the WFD objectives associated maintain the WFD quality, *i.e* Good status; and,
- Topographically down-gradient designated sites *i.e.* Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.

Pre-Controls/Design Potential Impact:

- Negative, indirect, imperceptible, medium-term, very unlikely impact on Poulacorey karst feature and Drumcliff Spring PWS;
- Negative, imperceptible, medium term, very unlikely impact on groundwater quality in the underlying aquifer (Ennis GWB) and the associated WFD objectives;
- Negative, indirect, imperceptible, medium-term, very unlikely impact on downstream surface water quality in the River Fergus and the associated WFD objectives; and,
- Negative, indirect, imperceptible, medium-term, very unlikely impact on Ballyalia Lake and associated designated sites - Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.

[2] Claire Cremin (MSc Thesis) - A Review of the contributing factors affecting water quality in the Drumcliff Springs, Co. Clare

Control Measures:

As discussed above, the ability of the proposed development to impact on groundwater quality is limited by the thick subsoils present at the site, which act as a protective buffer between the burial area and the underlying limestone aquifer.

The surface water drainage system will provide soakaway areas for runoff from paved areas and roads to infiltrate through, bypassing any grave areas. The diversion of this surface water to the soakaway pits reduces the volume of water infiltrating through any grave areas, thus diminishing any potential effect further.

Further control measures are not considered necessary due to:

- The thickness of subsoils present at the site (8.5-13.5m), which places the site within an area of Low-Moderate groundwater vulnerability (as per **Plate A**);
- The low-moderate infiltration rate;
- The elevated nature of the extension site relative to surrounding surface water bodies;
- The lack of groundwater presence at grave base depth (~1.8m); and,
- The historical data on groundwater quality at Pouladower swallow hole, indicates good quality water, with no increased levels of Ammonia (Poulacorey swallow hole ammonia rates were lower than Drumcliff Spring).

Residual Effects: The residual effect is – Negative, imperceptible, indirect, medium-term, highly unlikely impact on the above listed receptors.

Significance of Effects: For the reasons outlined above, no significant effects on the following receptors will occur as a result of the proposed development:

- Poulacorey karst feature (and associated link with Drumcliff Spring PWS);
- Underlying groundwater aquifer (Ennis GWB) and the WFD objectives associated with maintain the WFD quality status i.e Good quality;
- Down-gradient rivers including the River Fergus and the WFD objectives associated maintain the WFD quality *i.e* Good status;
- Ballyalia Lake, downgradient of the River Fergus and the WFD objectives associated maintain the WFD quality *i.e* Good status; and,
- Topographically down-gradient designated sites *i.e*. Ballyalia Lough SPA, Ballyalia Lake SAC & pNHA.

4.5 CUMULATIVE ASSESSMENT

In terms of hydrological and hydrogeological cumulative impacts arising from the proposed development, the cumulative impacts can occur during the construction and operational phase of the proposed development. During the construction phase, there is a heightened risk of hydrological impacts due to the nature of the construction activities at the site (entrainment of suspended solids, release of pollutants into the local watercourses etc). However, the construction phase of the project will be relatively short in nature, therefore limiting the potential for cumulative effects. Additionally, the implementation of the standard best practice mitigation measures outlined in **Section 4.3** above will ensure that there will be no deterioration in downstream surface water quality during the construction phase of the proposed development. Therefore, there will be no potential for cumulative effects to arise during the construction phase.

The potential for cumulative effects to arise during the operational phase of the proposed development is much reduced in comparison to the construction phase. During the operational phase, the hydrological regime at the site will be controlled by a range of sustainable drainage measures. All of the proposed drainage control measures are standard best practice and are proven techniques to manage surface waters within this type of development. These measures will ensure that the proposed development does not adversely impact downstream surface water/groundwater quality and/or quantity. Therefore, there will be no potential for cumulative effects to arise due to surface water drainage during the operational phase.

The proposed land use at the proposed development site (i.e. cemetery) has the potential to incur cumulative effects in conjunction with the existing cemetery located to the north. Based on the soil type and thickness and subsoil type and thickness, the potential for cumulative effects due to the natural decay process is limited (as outlined in **Section 4.4.2**). Historical data exists for the Poulacorey swallow hole, which shows no negative impacts on water quality due to the existing cemetery, in terms of Ammonia, with lower values at the Poulacorey swallow hole than at the downgradient Drumcliff spring. Due to the overall good protection of the groundwater aquifer from the subsoil layers (8.5-13.5m, which provides a Low-Moderate groundwater vulnerability risk rating as per the GSI matrix in **Plate A**), there is a low potential for cumulative effects on groundwater quality or surface water quality from the proposed development with respect to the existing Drumcliff cemetery.

5 SUMMARY AND CONCLUSIONS

- Hydro Environmental Services (HES) were requested by Clare County Council to undertake a Hydrological and Hydrogeological Assessment of a proposed extension to the Drumcliff Cemetery, situated along the Drumcliff Road, Ennis, Co. Clare.

- The following investigations were carried out by HES and other members of the Project Team:

  - Desk Study & Site Visit;

  - Trial Pitting and geological logging (5 no), Soakaway test to BRE Digest 365 (5 no.);

  - Geophysical survey (EM31 and Seismic Refraction) across 3 no. geophysics lines within the proposed development site; and,

  - HES has prepared a hydrological and hydrogeological environmental assessment report.

- Geological conditions encountered generally comprised a layer of topsoil (~0.25m) overlying reddish brown slightly sandy gravelly CLAY with occasional cobbles or grey/brown slightly sandy gravelly CLAY;

- Infiltration rates within the 5 no. trial pits were generally low to moderate, ranging between $2.77x10^{-6}$ to $6.25x10^{-6}$;

- Geophysical Investigation carried out determined 3 no. layers of soil/subsoil, with increasing strength or compaction to depths ranging between 8.5 – 13.5m. This indicates generally Low groundwater vulnerability (>10m subsoil) as outlined within the groundwater vulnerability classification scheme;

- The ground conditions encountered across the site indicate that groundwater is unlikely to be present within dug graves across the site;

- There are no direct hydrological connections between the site and downgradient surface water bodies. Standard separation distances (50m) to surface water features[3] are maintained by the proposed cemetery;

- The drainage design incorporated into the proposed development will ensure that surface water will be collected, treated and retained within the site, with infiltration to ground via 5 no. proposed soakaways;

- The conceptual site model of the site is outlined in Section 4.1 and in summary is conceptualised as a sloping site, underlain by thick clay-rich subsoils (8.5-13.5m) which form a drumlin feature overlying the limestone bedrock which forms the primary groundwater aquifer within the region. Low/moderate permeability rates indicate slow potential infiltration to groundwater within these subsoils into the underlying aquifer. From this conceptual model, surface water is considered to be the main potential pathway for potential effects, rather than groundwater;

- Potential topographically downgradient receptors include –

  - 1 no. karst feature (Poulacorey swallow hole) mapped 250m north of the proposed development site. The Poulacorey swallow hole is connected to the

[3] SEPA – Guidance on assessing the impacts of Cemeteries on Groundwater

Drumcliff Spring PWS (1km south). The recommended separation distance to drinking water supplies is 250m (SEPA Guidelines, refer to Footnote 3), which is maintained in this instance; and,

- o The Ballyalia Lake pNHA and SAC and Ballyalia Lough SPA are situated ~200m north of the site.

- An assessment of potential impacts on downgradient receptors has been completed within **Section 4** of this report. Proven and effective drainage management techniques have been incorporated into the design, to ensure surface water impacts on downgradient receptors will not occur. All surface water runoff generated from hardstanding areas within the site will be retained on-site and allowed to recharge to ground via 5 no. soakaways;

- The impact assessment process has concluded that there will be no significant effects on downgradient surface water bodies as a result of the proposed development;

- An impact assessment of potential groundwater effects has also been completed. Due to the underlying thickness of subsoils, which provide a substantial protective layer to the underlying aquifer and the geophysical inference of good, clean, non-karstified limestone underlying the proposed extension site, the conclusion of the assessment process is that there will be no significant effects on groundwater quality as a result of the proposed development; and,

- During the operational phase, the hydrological regime at the site will be controlled by a range of sustainable drainage measures. There will be no cumulative impacts on surface water quality or quantity, with respect to the existing Drumcliff cemetery (Section E) as a result of the proposed development. In terms of groundwater cumulative impacts, the burial and natural breakdown of remains within the proposed extension will lead to increased levels of certain nutrients such as Ammonia and Nitrate within the grave plots. Due to the thickness of subsoils (8.5-13.5m) and the low-moderate permeability of the subsoil, cumulative impacts, with respect to the existing Drumcliff cemetery, are not expected to occur.

* * * * * * * * * * * * * * * * * * * *

6 REFERENCES

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Deakin, J. and Daly, D.	1999	County Clare Groundwater Protection Scheme. Joint GSI/Clare County Council report
Deakin, J. and Daly, D.	2000	Ennis Public Supply Drumcliff Spring Co. Clare Groundwater Source Protection Report
Ground Investigations Ireland	April 2022	Drumcliff Burial Grounds Clare Co. Council, Ground Investigation Report, Project No 11545-03-22
Claire Cremin (IT Sligo)	June 2005	A Review Of The Contributory Factors Affecting Water Quality In The Drumcliff Springs, Co. Clare

APPENDIX I: SITE INVESTIGATION REPORT

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Ground Investigations Ireland

Drumcliff Burial Grounds

Clare Co. Council

Ground Investigation Report

April 2022

GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

DOCUMENT CONTROL SHEET

Project Title	Drumcliff Burial Grounds
Engineer	SDS
Client	Clare Co. Council
Project No	11545-03-22
Document Title	Ground Investigation Report

Rev.	Status	Author(s)	Reviewed By	Approved By	Office of Origin	Issue Date
A	Final	T McIntyre	E Byrne	A McDonnell	Dublin	22 April 2022

Ground Investigations Ireland Ltd. present the results of the fieldworks and laboratory testing in accordance with the specification and related documents provided by or on behalf of the client The possibility of variation in the ground and/or groundwater conditions between or below exploratory locations or due to the investigation techniques employed must be taken into account when this report and the appendices inform designs or decisions where such variation may be considered relevant. Ground and/or groundwater conditions may vary due to seasonal, man-made or other activities not apparent during the fieldworks and no responsibility can be taken for such variation. The data presented and the recommendations included in this report and associated appendices are intended for the use of the client and the client's geotechnical representative only and any duty of care to others is excluded unless approved in writing.

GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

CONTENTS

APPENDICES

1.0 Preamble

On the instructions of SDS Engineers, a site investigation was carried out by Ground Investigations Ireland Ltd., in April 2022 at the site of the proposed Burial ground extension in Drumcliff, Co. Clare.

2.0 Overview

2.1. Background

It is proposed to extend the current burial ground with associated plots and access roads at the proposed site. The site is currently greenfield.

2.2. Purpose and Scope

The purpose of the site investigation was to investigate subsurface conditions utilising a variety of investigative methods in accordance with the project specification. The scope of the work undertaken for this project included the following:

- Visit project site to observe existing conditions
- Carry out 5 No. Trial Pits to a maximum depth of 1.90m BGL
- Carry out 5 No. Soakaways to determine a soil infiltration value to BRE digest 365
- Report with recommendations

3.0 Subsurface Exploration

3.1. General

During the ground investigation a programme of intrusive investigation specified by the Consulting Engineer was undertaken to determine the sub surface conditions at the proposed site. Regular sampling and in-situ testing was undertaken in the exploratory holes to facilitate the geotechnical descriptions and to enable laboratory testing to be carried out on the soil samples recovered during excavation and drilling.
The procedures used in this site investigation are in accordance with Eurocode 7 Part 2: Ground Investigation and testing (ISEN 1997 – 2:2007) and B.S. 5930:2015.

3.2. Trial Pits

The trial pits were excavated using a 3T tracked excavator at the locations shown in the exploratory hole location plan in Appendix 1. The locations were checked using a CAT scan to minimise the potential for encountering services during the excavation. The trial pits were sampled, logged and photographed by a Engineering Geologist prior to backfilling with arisings. Notes were made of any services, inclusions, pit stability, groundwater encountered and the characteristics of the strata encountered and are presented on the trial pit logs which are provided in Appendix 2 of this Report.

3.3. Soakaway Testing

The soakaway testing was carried out in selected trial pits at the locations shown in the exploratory hole location plan in Appendix 1. These pits were carefully excavated and filled with water to assess the infiltration characteristics of the proposed site. The pits were allowed to drain and the drop in water level was recorded over time as required by BRE Digest 365. The pits were logged prior to completing the soakaway test and were backfilled with arising's upon completion. The soakaway test results are provided in Appendix 3 of this Report.

3.4. Surveying

The exploratory hole locations have been recorded using a KQ GEO Technologies KQ-M8 System which records the coordinates and elevation of the locations to ITM as required by the project specification. The coordinates and elevations are provided on the exploratory hole logs in the appendices of this Report.

4.0 Ground Conditions

4.1. General

The ground conditions encountered during the investigation are summarised below with reference to insitu and laboratory test results. The full details of the strata encountered during the ground investigation are provided in the exploratory hole logs included in the appendices of this report.

The sequence of strata encountered were consistent across the site and generally comprised;

- Topsoil
- Made Ground
- Cohesive Deposits

TOPSOIL: Topsoil was encountered in all the exploratory holes and was present to a maximum depth of 0.25m BGL.

MADE GROUND: Made ground deposits were encountered in IF1 to a depth of 0.70m and were described as *grey very clayey sandy sub-rounded to rounded fine to coarse Gravel.* Occasional or frequent cobble and boulder content is present where noted on the exploratory hole logs.

COHESIVE DEPOSITS: Cohesive deposits were encountered beneath the Made Ground and were described typically as *reddish brown slightly sandy gravelly CLAY with occasional cobbles* or *grey/brown slightly sandy gravelly CLAY*. The secondary sand and gravel constituents varied across the site and with depth, with granular lenses occasionally present in the glacial till matrix. These deposits had some, occasional or frequent cobble and boulder content where noted on the exploratory hole logs.

4.2. Groundwater

No groundwater was noted during the investigation however we would point out that these exploratory holes did not remain open for sufficiently long periods of time to establish the hydrogeological regime and groundwater levels would be expected to vary with the time of year, rainfall, nearby construction and other factors. Surface water was present in close proximity to IF3, however this likely due to the impermeable nature of the Topsoil in that area.

5.0 Recommendations & Conclusions

5.1. General

The recommendations given and opinions expressed in this report are based on the findings as detailed in the exploratory hole records. Where an opinion is expressed on the material between exploratory hole locations, this is for guidance only and no liability can be accepted for its accuracy. No responsibility can be accepted for conditions which have not been revealed by the exploratory holes. Limited information has been provided at the ground investigation stage and any designs based on the recommendations or conclusions should be completed in accordance with the current design codes, taking into account the variation and the specific details contained within the exploratory hole logs.

5.2. Excavations

Short term temporary excavations in the cohesive deposits will remain stable for a limited time only and will require to be appropriately battered or the sides supported if the excavation is below 1.25m BGL or is required to permit man entry.

Excavations in the soft Cohesive Deposits will require to be appropriately battered or the sides supported due to the low strength of these deposits.

The groundwater and stability noted on the trial pit logs should be consulted when determining the most appropriate construction methods for excavations.

5.3. Soakaway Design

Infiltration rates of f=6.257 x 10^{-6} m/s, f=4.685 x 10^{-6} m/s, f=4.446 x 10^{-6} m/s and 2.771 x 10^{-6} m/s respectively were calculated for the soakaway locations SA01, SA03, SA04 and SA05. At the location of SA02 the water level dropped too slowly to allow calculation of ‘f’ the soil infiltration rate.

APPENDIX 1 - Site Location Plan

Legend

Indicative Site Boundary

Site Location

Client:

SDS Structural Design Solutions Ltd

Project Code:
11545-03-22

Project Title:
Burial Grounds, Drumcliff

Drawing Title:
Figure 1 - Site Location

GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Ground Investigations Ireland Ltd.
Catherinstown House,
Hazelhatch Road,
Newcastle, Co. Dublin
www.gii.ie 01-6015175/5176

0 15 30 45 60 75 m

Drawn By:
BS

Date:
11/06/2020

Legend

Indicative Site Boundary

Soakaways

Client:

SDS Structural Design Solutions Ltd

Project Code:

11545-03-22

Project Title:

Burial Grounds, Drumcliff

Drawing Title:

Figure 2 - Soakaway Locations

GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Ground Investigations Ireland Ltd.
Catherinstown House,
Hazelhatch Road,
Newcastle, Co. Dublin
www.gii.ie 01-6015175/5176

0 10 20 30 40 50 m

Drawn By: TmcI

Date: 14/04/2022

APPENDIX 2 – Trial Pit Records

Ground Investigations Ireland Ltd www.gii.ie	Site: Drumcliff Burial Grounds	Trial Pit Number: IF1

Machine : 6T Excavator Method : Trial Pit	Dimensions: 1.60 x 0.40 x 1.90	Ground Level (mOD): 19.43	Client: SDS	Job Number: 11545-03-22
	Location: 533038 E 679989.8 N	Dates: 08/04/2022	Engineer:	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
				19.28	(0.15) 0.15	Brown slightly sandy slightly gravelly TOPSOIL with grass rootlets.		
				18.73	(0.55) 0.70	MADE GROUND: Grey very clayey sandy sub-rounded to rounded fine to coarse Gravel.		
				17.93	(0.80) 1.50	Soft brown/grey slightly sandy slightly gravelly CLAY.		
				17.53	(0.40) 1.90	Firm reddish brown slightly sandy gravelly CLAY with some cobbles.		
						Complete at 1.90m		

Plan

Remarks

No Groundwater encountered.
Trial pit stable.
Soakaway test completed in Trial Pit.
Trial pit backfilled on completion.

Scale (approx)	Logged By	Figure No.
1:25	Tmcl	11545-03-22.IF1

Ground Investigations Ireland Ltd www.gii.ie			Site: Drumcliff Burial Grounds	Trial Pit Number: IF2
Machine : 6T Excavator Method : Trial Pit	Dimensions	Ground Level (mOD): 20.80	Client: SDS	Job Number: 11545-03-22
	Location: 532998.8 E 679951.1 N	Dates: 08/04/2022	Engineer	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
				20.65	(0.15) 0.15	Brown slightly sandy slightly gravelly TOPSOIL with grass rootlets.		
				19.10	(1.55) 1.70	Stiff reddish brown slightly sandy gravelly CLAY with many rounded cobbles.		
						Complete at 1.70m		

Plan

Remarks

No Groundwater encountered.
Trial pit stable.
Soakaway test completed in Trial Pit.
Trial pit backfilled on completion.

Scale (approx)	Logged By	Figure No.
1:25	Tmcl	11545-03-22.IF2

Ground Investigations Ireland Ltd www.gii.ie	Site Drumcliff Burial Grounds	Trial Pit Number **IF3**

Machine : 6T Excavator **Method :** Trial Pit	**Dimensions** 2.30 x 0.35 x 1.90	**Ground Level (mOD)** 22.76	**Client** SDS	**Job Number** 11545-03-22
	Location 533071.1 E 679973.6 N	**Dates** 08/04/2022	**Engineer**	**Sheet** 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.20)	Brown slightly sandy slightly gravelly TOPSOIL with grass rootlets.		
				22.56	0.20	Soft reddish brown sandy slightly gravelly CLAY with occasional cobbles.		
					(1.70)			
				20.86	1.90	Complete at 1.90m		

Plan

Remarks

No Groundwater encountered.
Trial pit stable.
Soakaway test completed in Trial Pit.
Trial pit backfilled on completion.

Scale (approx)	Logged By	Figure No.
1:25	Tmcl	11545-03-22.IF3

Ground Investigations Ireland Ltd www.gii.ie	Site: Drumcliff Burial Grounds	Trial Pit Number: IF4

Machine : 6T Excavator Method : Trial Pit	Dimensions: 1.90 x 0.35 x 1.80	Ground Level (mOD): 26.71	Client: SDS	Job Number: 11545-03-22
	Location: 533014.6 E 679862.7 N	Dates: 08/04/2022	Engineer:	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.25)	Brown slightly sandy slightly gravelly TOPSOIL with grass rootlets.		
				26.46	0.25	Soft reddish brown slightly sandy gravelly CLAY with occasional cobbles.		
					(1.55)			
				24.91	1.80	Complete at 1.80m		

Plan

Remarks

No Groundwater encountered.
Trial pit stable.
Soakaway test completed in Trial Pit.
Trial pit backfilled on completion.

Scale (approx)	Logged By	Figure No.
1:25	Tmcl	11545-03-22.IF4

Ground Investigations Ireland Ltd www.gii.ie		Site: Drumcliff Burial Grounds	Trial Pit Number: IF5
Machine : 6T Excavator Method : Trial Pit	Dimensions: 1.90 x 0.35 x 1.80	Ground Level (mOD): 22.46	Client: SDS	Job Number: 11545-03-22
	Location: 532983.7 E 679895.1 N	Dates: 08/04/2022	Engineer:	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
				22.31	(0.15) 0.15	Brown slightly sandy slightly gravelly TOPSOIL with grass rootlets.		
				20.66	(1.65) 1.80	Soft reddish brown slightly sandy gravelly CLAY with some cobbles.		
						Complete at 1.80m		

Plan

Remarks

No Groundwater encountered.
Trial pit stable.
Soakaway test completed in Trial Pit.
Trial pit backfilled on completion.

Scale (approx)	Logged By	Figure No.
1:25	Tmcl	11545-03-22.IF5

APPENDIX 3 – Soakaway Results

GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

IF1

Soakaway Test to BRE Digest 365
Trial Pit Dimensions: 1.60m x 0.40m x 1.80m (L x W x D)

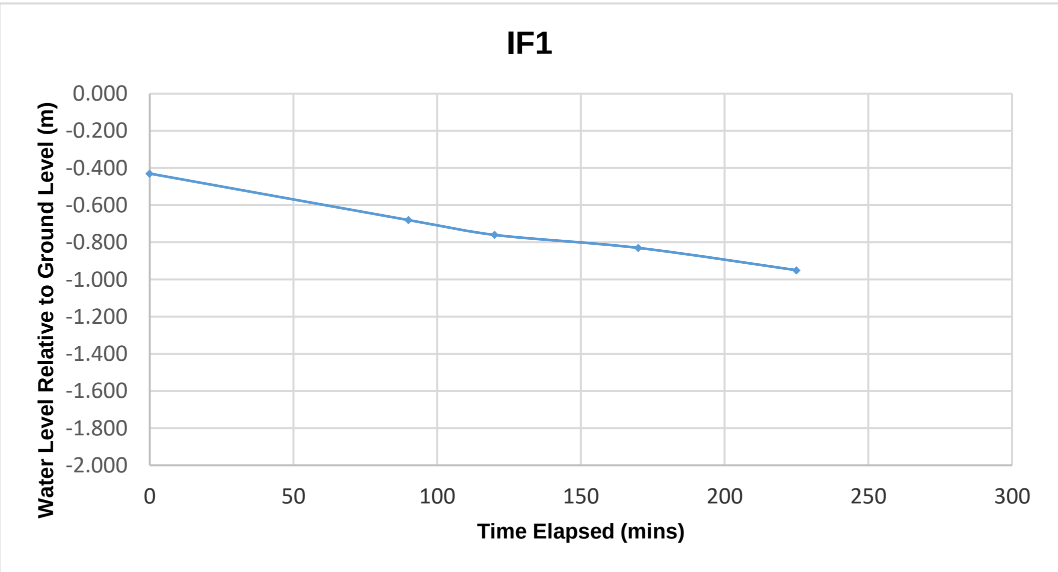
Date	Time	Water level (m bgl)
13/04/2022	0	-0.430
13/04/2022	90	-0.680
13/04/2022	120	-0.760
13/04/2022	170	-0.830
13/04/2022	225	-0.950

Start depth	Depth of Pit	Diff	75% full	25%full
0.43	1.900	1.470	0.7975	1.5325

Length of pit (m)	Width of pit (m)	75-25Ht (m)	Vp75-25 (m3)
1.600	0.400	0.735	0.47

Tp75-25 (from graph) (s)	21000	50% Eff Depth	ap50 (m2)
		0.735	3.58

f = 6.257E-06 m/s



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Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

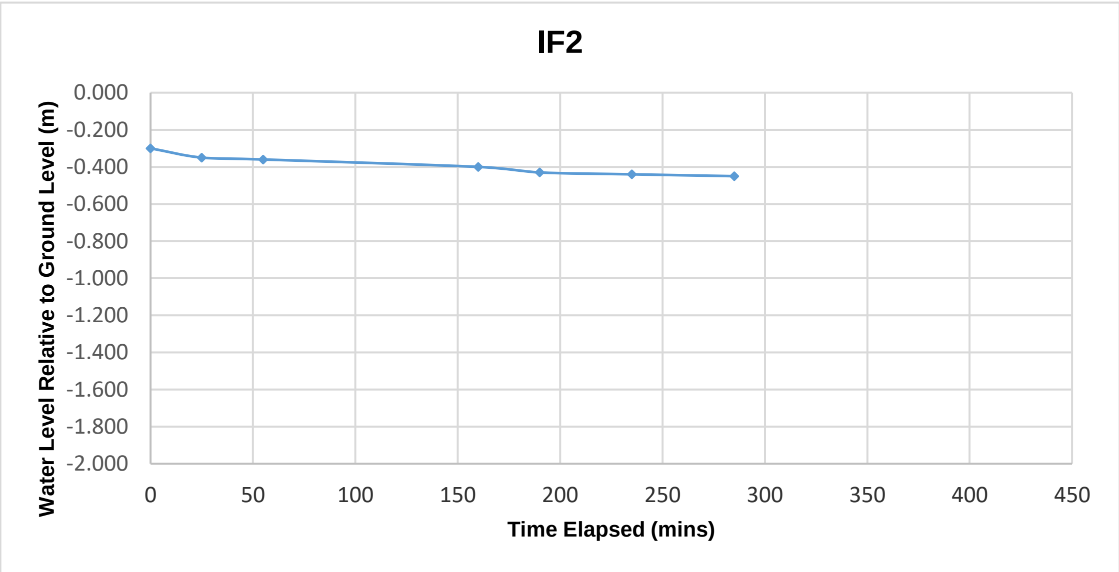
IF2

Soakaway Test to BRE Digest 365
Trial Pit Dimensions: 1.9m x 0.35m x 2.0m (L x W x D)

Date	Time	Water level (m bgl)
13/04/2022	0	-0.300
13/04/2022	25	-0.350
13/04/2022	55	-0.360
13/04/2022	160	-0.400
13/04/2022	190	-0.430
13/04/2022	235	-0.440
13/04/2022	285	-0.450

***Soakaway failed - Pit backfilled**

Start depth	Depth of Pit	Diff	75% full	25%full
0.30	2.000	1.700	0.725	1.575



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Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

IF3

Soakaway Test to BRE Digest 365
Trial Pit Dimensions: 1.90m x 0.350m x 1.90m (L x W x D)

Date	Time	Water level (m bgl)
13/04/2022	0	-0.810
13/04/2022	38	-0.860
13/04/2022	115	-0.980
13/04/2022	145	-1.010
13/04/2022	192	-1.040
13/04/2022	235	-1.110

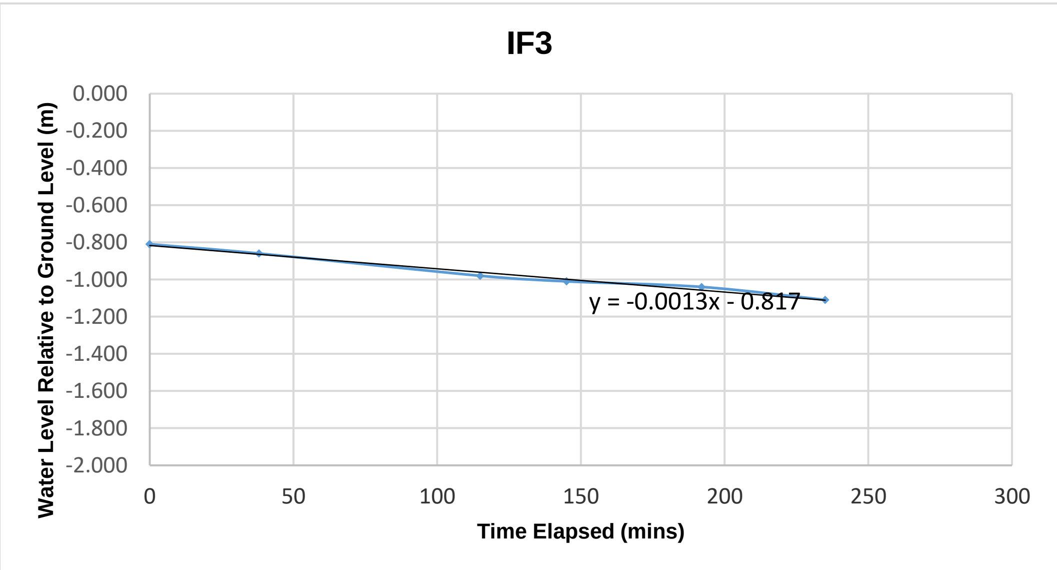
Start depth	Depth of Pit	Diff	75% full	25%full
0.81	**1.900**	**1.090**	**1.0825**	**1.6275**

Length of pit (m)	Width of pit (m)	75-25Ht (m)	Vp75-25 (m3)
2.300	0.350	0.545	0.44

Tp75-25 (from graph) (s) **25500**

50% Eff Depth	ap50 (m2)
0.545	3.6935

f = 4.658E-06 m/s



GROUND INVESTIGATIONS IRELAND
Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

IF4

Soakaway Test to BRE Digest 365
Trial Pit Dimensions: 1.90m x 0.350m x 1.80m (L x W x D)

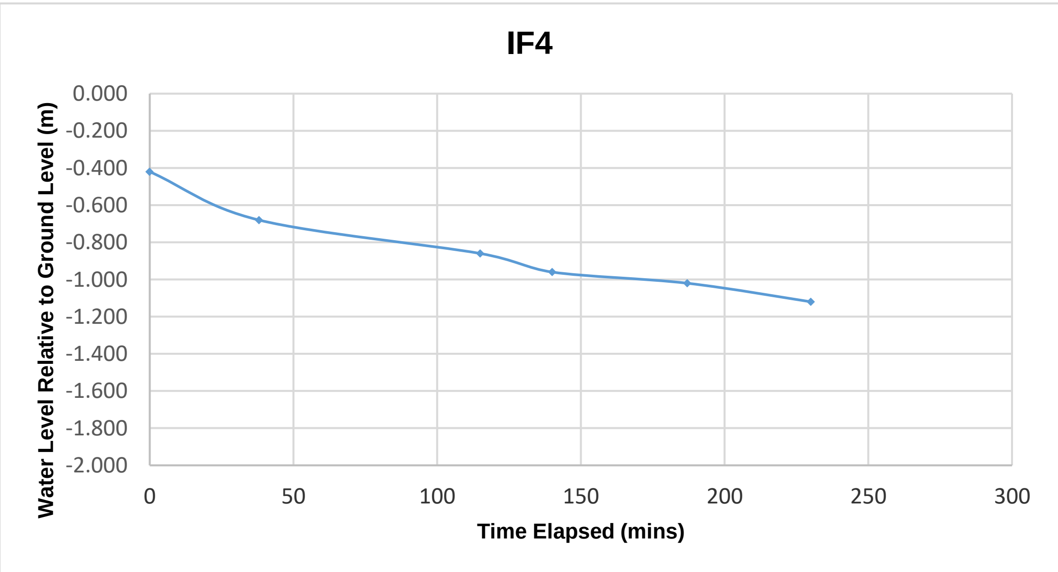
Date	Time	Water level (m bgl)
13/04/2022	0	-0.420
13/04/2022	38	-0.680
13/04/2022	115	-0.860
13/04/2022	140	-0.960
13/04/2022	187	-1.020
13/04/2022	230	-1.120

Start depth	Depth of Pit	Diff	75% full	25%full
0.42	**1.800**	**1.380**	**0.765**	**1.455**

Length of pit (m)	Width of pit (m)	75-25Ht (m)	Vp75-25 (m3)
2.300	0.350	0.690	0.56

Tp75-25 (from graph) (s)	**28000**	50% Eff Depth	ap50 (m2)
		0.690	4.462

f = 4.446E-06 m/s



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Geotechnical & Environmental

Catherinestown House,
Hazelhatch Road,
Newcastle,
Co. Dublin.
D22 YD52

Tel: 01 601 5175 / 5176
Email: info@gii.ie
Web: www.gii.ie

IF5

Soakaway Test to BRE Digest 365
Trial Pit Dimensions: 1.90m x 0.350m x 1.80m (L x W x D)

Date	Time	Water level (m bgl)
13/04/2022	0	-0.470
13/04/2022	33	-0.610
13/04/2022	48	-0.760
13/04/2022	108	-0.810
13/04/2022	179	-0.860
13/04/2022	231	-0.920

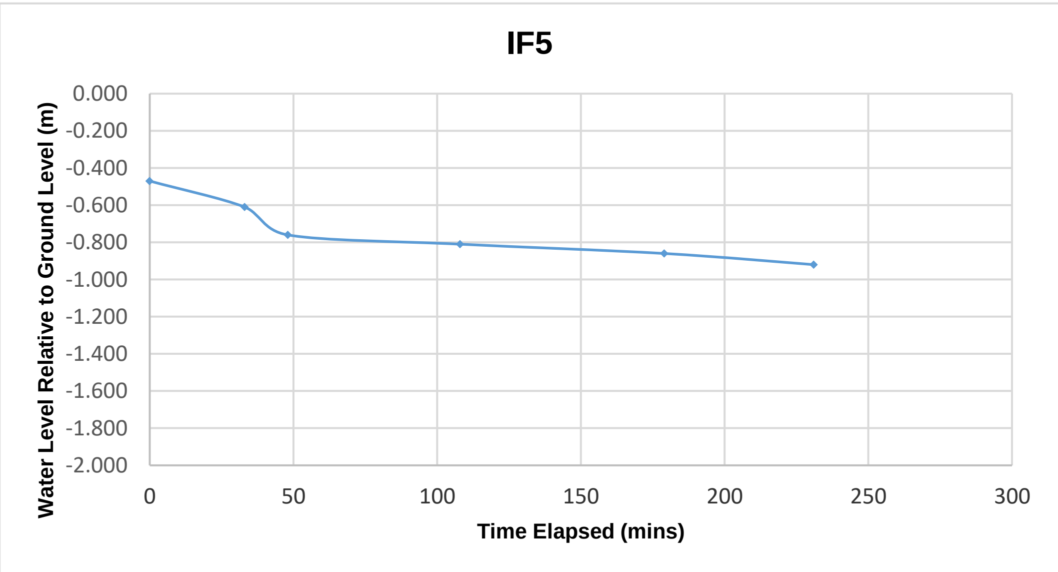
Start depth	Depth of Pit	Diff	75% full	25%full
0.47	1.800	1.330	0.8025	1.4675

Length of pit (m)	Width of pit (m)	75-25Ht (m)	Vp75-25 (m3)
2.200	0.350	0.665	0.51

Tp75-25 (from graph) (s) **44400**

50% Eff Depth	ap50 (m2)
0.665	4.1615

f = 2.771E-06 m/s



APPENDIX II: GEOPHYSICAL SURVEY REPORT

Drumcliffe Cemetery

Ennis, Co. Clare

Geophysical Survey

Report Status: Draft

MGX Project Number: 6667

MGX File Ref: 6667d-005.doc

21st December 2022

Confidential Report To:

Hydro-Environmental Services
Dungarvan
Co. Waterford

Clare County Council
Aras Contae an Clair
New Road
Ennis
Co. Clare

Report submitted by:
Minerex Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare, W23X7Y5
Ireland
Tel.: 01-6510030
Email: info@mgx.ie

Issued by:

Author: John Connaughton (Geophysicist)

Reviewer: Hartmut Krahn (Senior Geophysicist)

Minerex Geophysics Limited

Subsurface Geophysical Investigations

EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of EM31 Ground Conductivity, 2D-Resistivity and seismic refraction (p-wave) surveying for the ground investigation for the proposed extension of the Drumcliffe Cemetery in Ennis, County Clare.
2. The main objectives of the survey were to determine the ground conditions under the site, to determine the depth to rock and the overburden thickness, to estimate the strength or stiffness or compaction of overburden and the rock quality, to determine preferential ground water flows, and to detect possible karstified rock.
3. All the geophysical results show uniformity across the survey area with little variation across the site.
4. The EM31 Ground Conductivity data indicates boulder clay underlying the site. There is also an underground metal pipe indicated.
5. The 2D-Resistivity shows a thick layer of boulder clay which could be described as sandy gravelly clay and silt with cobbles and boulders.
6. The seismic refraction data was modelled with four layers and ties in well with the 2D-Resistivity data.
7. Layer 1 is described as soft or loose soil. This layer is up to 2m deep across the site.
8. Layer 2 is interpreted as very stiff boulder clay. This layer extends to depths of 2.5 – 5.5m below ground level (bgl)
9. Layer 3 is interpreted as hard boulder clay. This layer has a thickness of 4 – 9.5m.
10. The top of the good to very good limestone is interpreted at depths of 8.5 – 13.5m bgl.
11. The survey area is underlain by a thick layer of highly consolidated boulder clay.
12. This overburden would have a low ground water permeability.
13. There is no indication of karstified limestone within the underlying bedrock to the depth of the survey. The thick highly consolidated boulder clay overlying the limestone would provide good protection from any potential karstified limestone being affected by ground water flows.

CONTENTS

List of Tables, Maps and Figures:

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey for an extension of the Drumcliffe Cemetery in Ennis, Co. Clare. The survey consisted of EM31 ground conductivity, 2D-Resistivity and seismic refraction (p-wave) measurements. The survey was commissioned by Hydro-Environmental Services.

This survey utilized various complimentary geophysical methods to improve final interpretations. The role of geophysics as a non-destructive fast method is to provide a geological interpretation over a wide area to complement direct ground investigations at specific locations. The direct ground investigation results can be used to improve the initial geophysical results and interpretation.

The survey was aimed both at investigating the ground conditions and to indefinity potential groundwater flow paths under the site.

1.2 Objectives

The main objectives of the geophysical survey were:

- To determine the ground conditions under the site
- To determine the depth to rock and the overburden thickness
- To estimate the strength or stiffness or compaction of overburden materials and the rock quality
- To determine the type of overburden and rock
- To detect lateral changes within the geological layers
- To detect possible karstified zones within the rock or karst features
- To identify potential groundwater flow paths under the site

1.3 Site Description

The site is located in the southeast corner of the existing Drumcliffe Cemetery. There is a track which runs through the cemetery to the survey location. The NW part of the survey area is within the cemetery ground while the rest of the area is within an agricultural grass field. The Drumcliffe Water Treatment Plant borders the site to the SE.

Elevations on site rise from 19.3mOD in the NW to 31.7 in the SE.

1.4 Geology

Online geological maps of Ireland (GSI, 2022) give the following information:

The overburden geology consists of till derived from limestones.

In terms of rock the survey area is underlain by the Burren Formation, described as pale grey clean skeletal limestone.

The Burren formation is karstifiable and there is a swallow hole noted just north of the cemetery. The path of the underground watercourse is towards the south and it is shown as passing under the survey area. The connection has been proven by tracer tests by the Geological Survey of Ireland.

There are no faults or shallow rock recorded near the site.

1.5 Report

This report includes the results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the results of the survey. More detailed descriptions of geophysical methods and measurements can be found in GSEG (2002), Milsom (1989) and Reynolds (1997).

The description of soil, rock and the use of geotechnical terms (soft, stiff, dense etc) follows Eurocode (2007) and BSI (2015) standards. The terms are defined in the standards and the physical parameters are related from experience. This geophysical survey has been acquired, processed, interpreted and reported in accordance with these guidelines.

A digital OSI map was provided by the client and is used as the background map in this report. Elevations were surveyed on site and are used in the vertical sections.

The interpretative nature and the non-invasive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data, give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology consisted of using EM31 Ground Conductivity measurements across the site and 2D-Resistivity surveying and Seismic Refraction surveying, along proposed locations crossing the survey area.

The survey locations are indicated on Map 1. The lines, and parameters are tabulated in Table 1.

Table 1: Geophysical Survey Locations and Acquisition Parameters

Resistivity Line	**Electrode Spacing/m**	**Number of Electrodes**	**Line Length/m**
R1	3	40	117
R2	3	32	93
R3	3	77	228
SUM			**438**
Seismic Line	**Geophone Spacing/m**	**Number of Geophones**	**Line Length/m**
S1	3	40	117
S2	3	32	93
S3	3	77	228
SUM			**438**

2.2 EM31 Ground Conductivity

The EM31 ground conductivity survey was carried out over the area indicated in Map 1 on lines nominally 10 m apart. Along each line a reading of ground conductivity was taken every second while walking along, thereby resulting in a survey grid of nominally 10 x 2 m. The locations were measured with a sub-meter accuracy SERES DGPS system attached to the EM31 and all data was jointly stored in a data logger. The conductivity meter was a GEONICS EM31 with Archer2 data logger and NAV31 data acquisition software. The instrument was compared to base station readings and no EM drift was recorded.

EM31 ground conductivity determines the bulk conductivity of the subsurface over a typical depth between 0 and 6m bgl. and over a radius of approx. 5m around the instrument. When looking for clay, silt and water infill within rock occurring at relatively shallow depth the EM31 can find anomalous rock zones with a vertical extent of approx. 3m. The measurements are disturbed by metal and other conductive objects in close proximity to the instrument, and therefore no geological interpretations can be made in the vicinity of such man-made objects. Either readings were not taken near sources of interference, or notes were taken by the surveyor in order to remove these during processing or to account for these in the interpretation.

2.3 2D-Resistivity (ERT)

2D-Resistivity lines were surveyed with electrode spacing of 3m, up to 64 electrodes per set-up and a maximum length of 189m per set-up. The readings were taken with a Tigre Resistivity Meter, Imager Cables, stainless steel electrodes and a laptop with ImagerPro acquisition software.

During 2D-Resistivity surveying, data is acquired in the form of linear arrays using a suite of metal electrodes. A current is induced into the ground via a pair of electrodes whilst a potential difference is measured across a second pair of electrodes. This allows for the recording of the apparent resistivity in a two-dimensional arrangement below the line. The data is inverted after the survey to obtain a model of subsurface resistivities. The generated model resistivity values and their spatial distribution can then be related to typical values for different geological materials.

The penetration depth of a resistivity set-up increases towards the centre where it reaches depths of over 15m.

2D-Resistivity has previously proven zones of anomalous or karstified rock with lateral extents of 5m and more.

2.4 Seismic Refraction

Seismic refraction lines were surveyed with geophone spacing of 3m and 24 geophones per set-up resulting in a 69m length per set-up. The recording equipment consisted of a 24 Channel GEOMETRICS ES-3000 engineering seismograph with 4.5Hz vertical geophones. The seismic energy source consisted of a hammer and plate. A zero-delay trigger was used to start the recording. Normally 7 shot points per p-wave set-up were used.

Set-ups were acquired in longer continuous lines using common shot points between set-ups and concatenating into longer lines at the processing stage.

The seismic refraction survey method focuses on propagating p-waves travelling through the subsurface, which are generated by hitting a hammer on a plate or other source. As the wave propagates through the subsurface, its velocity varies as it travels through overburden, rock with different elastic properties, and along geological boundaries. Velocity data is recorded via the surveying equipment, which is then processed, allowing geological layer thicknesses and boundaries to be established.

Seismic Refraction generally determines the depth to horizontal or near horizontal layers where the compaction or strength or rock quality changes with an accuracy of around 20% of the depth to that layer.

Where the layers are shallower than the geophone spacing depth deviations of +- 1m to top of layers can occur. Where low velocity layers or shadow zones are present (e.g., below solid ground surface) or where layers dip with more than 20 degrees angle the accuracy becomes much less.

The seismic refraction set-ups with 69m individual length have a reasonable penetration depth of around 15m. An internationally accepted maximum depth estimate for a seismic refraction set-up is 1/6 of the set-up length including offshots. The depth penetration varies according to the velocity structure of the subsurface. In this report we used a depth of 15m bgl. where the seismic modelling was ended as deeper modelling becomes less meaningful.

2.5 Site Work

The data acquisition was carried out between the 15th and 16th of December 2022. The weather conditions were fair throughout the acquisition period. Health and safety standards were adhered to at all times. The locations and elevations were surveyed with a Carlson NR3 RTK-GPS to accuracy < 0.05m.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was executed utilizing the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site, and the experience of the authors.

3.1 EM31 Ground Conductivity

The EM31 ground conductivity values were contoured and gridded with the SURFER contouring package. The contours are created by gridding and interpolation and care must be taken when using the data. The contour map is overlaid over the location and base map (Map 2) and the values in milliSiemens/metre (mS/m) are indicated on the colour scale bar.

The natural conductivity levels are very uniform across the survey area ranging from 5 to 9 mS/m. This indicates a boulder clay overburden across the survey area with little variation in composition. The negative and very low readings (Blue) along the north indicate a line of buried metal (like a pipe) while the higher readings (Red) along the border of the cemetery and in the SE along the boundary with the Water Treatment Plant are due to interference from metal fencing. The line of slightly higher conductivities (Yellow) running NW-SE is related to a former field boundary.

3.2 2D-Resistivity (ERT)

The 2D-Resistivity data was positioned and inverted with the RES2DINV inversion package. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available and for this project the Jacobian Matrix was recalculated for the first three iterations, then a Quasi-Newton approximation was used for subsequent iterations. Each dataset was inverted using seven iterations resulting in a typical RMS error of <3.0%. The resulting models were colour contoured with the same resistivity scale for all lines and they are displayed as cross sections (Figure 1).

Resistivities are characteristic for certain overburden and rock types. If there is a high content of clay minerals (which are electrically conductive) then the overburden resistivity will be lower than as if there is a high content of clastic grains like sand or gravel. The purer the clay and the lower the sand and gravel content, the lower the resistivity. Water content in overburden layers can influence the resistivities, but generally clay content has a more dominating effect.

Within bedrock types like clean limestone, high resistivities indicate a fresh, strong, unweathered rock. As the weathering in the rock increases the resistivity gets lower because of weathering products, remineralisation of rock and infill of cracks, faults and voids with clay and water. Weathering within rock is typically indicated by lower resistivity values in the cross sections.

The resistivities cover a range typical for materials from clay rich overburden (low resistivities) to fresh strong unweathered bedrock (high resistivities). The ranges have been taken into the consideration for the interpretation. The overburden on this site is dominated by medium resistivity values (125 - 500 Ohmm) which typically indicate a boulder clay. High resistivities at depth (>500 Ohmm) indicate a clean limestone bedrock.

3.3 Seismic Refraction

The seismic refraction data was positioned and processed with the SEISIMAGER software package to give a layered model of the subsurface. The number of layers has been determined by analysing the seismic traces and 4 layers were used in the models. All seismic lines were subject to a standardised processing sequence which consisted of a topographic correction which was based on integrated elevation data, first break picking, tomographic inversion, travel-time computation via ray-tracing and velocity modelling. Residual deviations of typically 0.4 to 1.8 msec RMS have been obtained for each line. Following each processing stage QC procedures were adhered to. The resulting layer boundaries are shown as thick lines overlaid on the 2D-Resistivity cross sections (Figure 1). The average seismic velocities obtained within the layers are annotated on the sections as bold black numbers.

The p-wave seismic velocity is closely linked to the density of subsurface materials and to parameters like compaction, stiffness, strength and rock quality. The higher the density of the subsurface materials the higher the seismic velocity. More compacted, stiffer, denser and stronger material will have a higher seismic velocity. For rock, the seismic velocity is higher when the rock is stronger, less weathered and has a higher quality. If the rock is more weathered, broken, fractured, fissured or karstified then the seismic velocity will be reduced compared to that of intact fresh rock.

Because of the above relationship, the seismic refraction method and seismic velocities are suitable to investigate ground where the layers get denser, more compacted and stronger with depth. A disadvantage is that some materials may have the same seismic velocity hard or very dense highly consolidated overburden and a weathered rock can have the same seismic velocity range (as could be the case in the layer 3 below).

The modelled seismic data has created the following layered ground model:

Layer 1 has a thickness of up to 2m and seismic velocities of 200 - 300m/s. This overburden would be soil with a soft or loose stiffness or compaction.

Layer 2 was modelled with a velocity of 1600m/s and reaches a depth between 2.5 and 5.5m. The velocity indicates overburden material with very stiff strength or compaction.

Layer 3 velocities of 2400m/s indicate predominantly overburden with hard strength or compaction. The thickness or depth varies between 4 and 9.5 m.

Strong rock is indicated by seismic velocities of 4500m/s and the top of this strong rock varied between 8.5 and 13.5m.

3.4 Interpretation of Resistivity and Seismic Refraction

Table 2 summarises the interpretation. The stiffness or compaction and the rock strength or quality have been estimated from the seismic velocity. The estimation of the excavatability for the bedrock has been made according to the caterpillar chart published in Reynolds (1997). The geotechnical assessment for rippability will have to take factors like rock type and jointing into account and the estimation in this report is solely based on the seismic velocities.

Interpreted cross sections are shown in Figure 2. The interpretation has been made from all available information. For overburden layers and the top of the rock the seismic refraction data has been used as seismic refraction is the best method to delineate layer boundaries. The resistivity models have been used to delineate two generalised types of rock and to indicate rock head where no seismic refraction data was acquired. Resistivity data is better suited to show rock types and features within the rock while seismic refraction velocities are indicating the change of compaction, stiffness or rock quality with depth. Along short sections where only one data type is available an interpolation for the interpreted layers was made.

Table 2: Summary of Interpretation

Layer	**General Seismic Velocity Range (m/sec)**	**General Resistivity Range (Ohmm)**	**Stiffness or Compaction or Rock Quality**	**Interpretation**	**Estimated Excavation Method**
1	200 - 300	Any	Soft or Loose	Soil	Diggable
2	1600	125 - 500	Very stiff	Boulder Clay	Diggable
3	2400	125 - 250	Hard	Boulder Clay	Diggable
4	4500	>500	Good to very good rock	Clean Limestone	Breaking & Blasting

4. CONCLUSIONS

The following conclusions are made:

- The geophysical surveys carried out for the Drumcliffe Cemetery extension consisted of EM31 Ground Conductivity, 2D-Resistivity and seismic refraction surveying.
- At all locations there was a strong correlation between all three geophysical survey methods.
- The EM31 Ground Conductivity data shows a consistent boulder clay overburden throughout the survey area.
- The 2D-Resistivity data shows thick boulder clay across all three lines. High resistivities at depth indicate a clean limestone bedrock.
- The seismic refraction data was modelled with a total of four layers.
- Layer 1 is interpreted as soft or loose soil. This layer is up to 2m thick.
- Layer 2 reaches depths of 2.5 – 5.5m bgl and is interpreted as very stiff boulder clay.
- Layer 3 is described as hard boulder clay and has a thickness of 4– 9.5m.
- The top of the good to very good limestone layer (Layer4) is found at depths of 8.5 – 13.5m bgl.
- The data is very unform across the survey area with only small variations in the overburden composition and rock depth across the site.
- The thick layer of clay dominated boulder clay would cause low ground water permeability.
- Within the rock layer there is no indication of karstified limestone. The thick overlying highly consolidated glacial till will provide good protection from any underlying karstified limestone that may be present deeper than the survey depth.

5. REFERENCES

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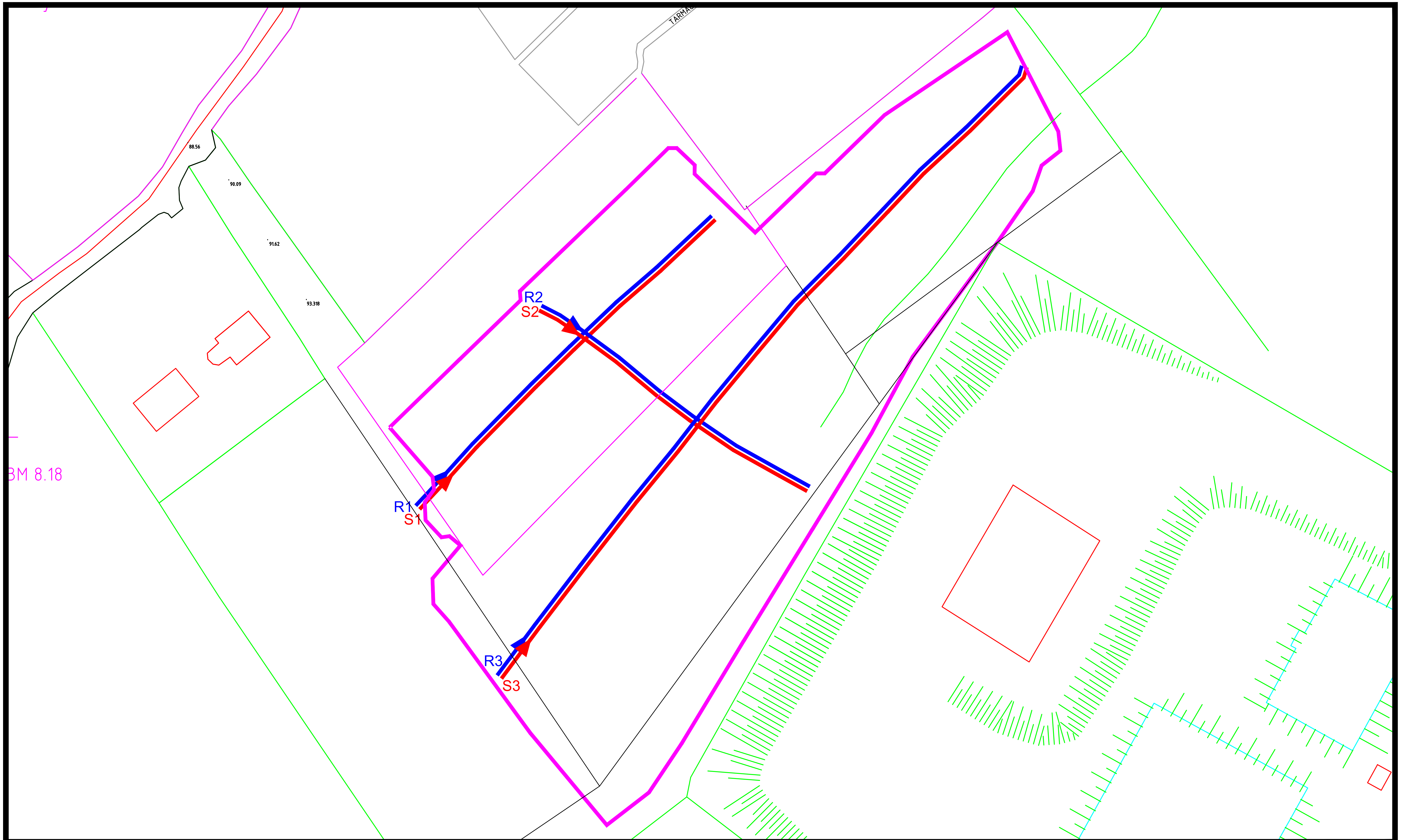
7. **Weaver, 1975.** Geological Factors significant in the Assessment of Rippability, 1975



Minerex
Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Email: info@mgx.ie
Web: www.mgx.ie

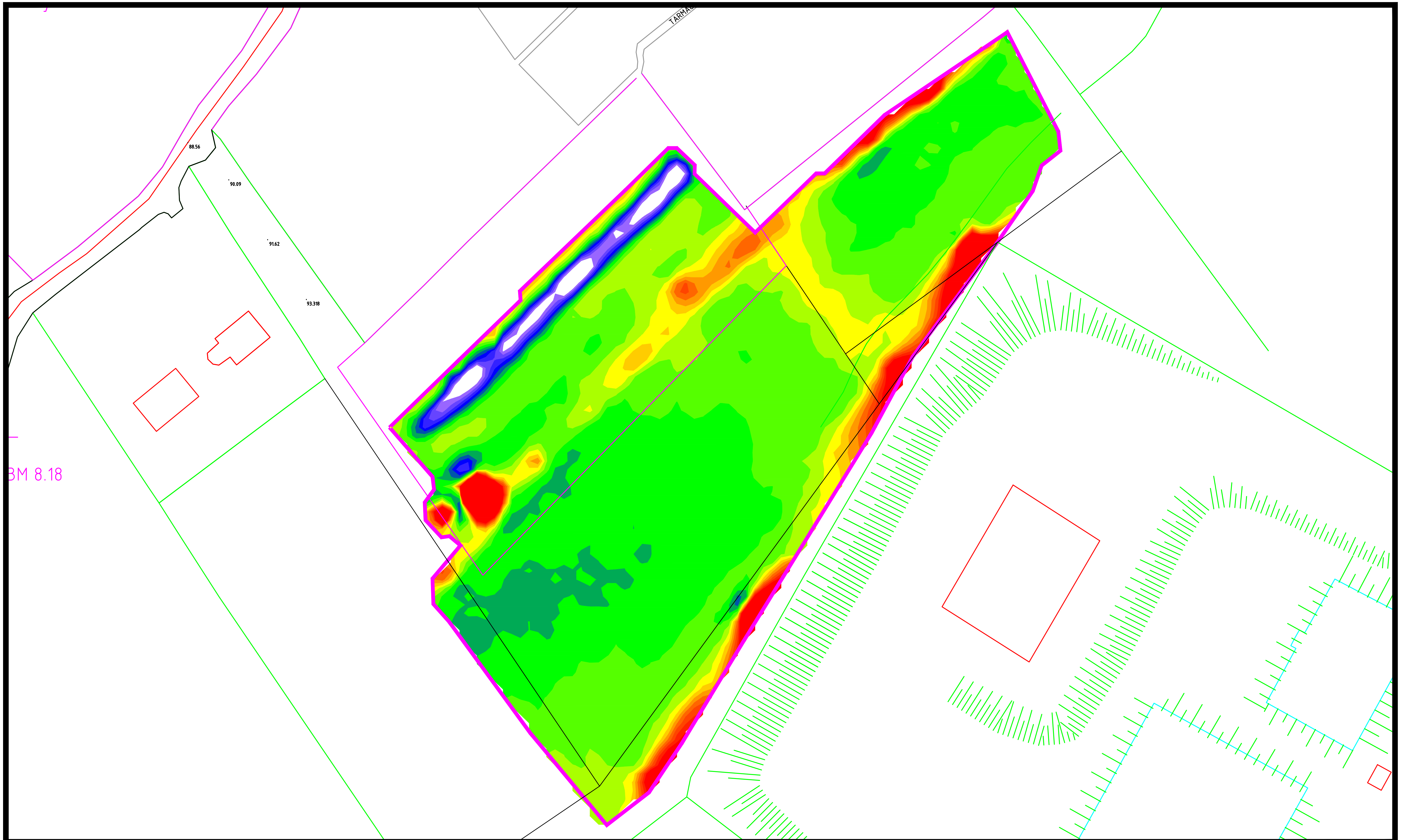
CLIENT	Hydro Environmental Services Clare County Council
PROJECT	Drumcliffe Cemetery, Co. Clare Geophysical Survey
TITLE	Map 1: Geophysical Survey Location Map

SCALE:	1:1000 @ A3
PROJECT:	6667
DRAWN:	JS
DATE:	20/12/2022
MGX FILE:	6667d_Drawings.dwg
STATUS:	Draft

Geophysical Survey Locations:

R2	2D-Resistivity Line
S1	Seismic Refraction Line
	EM31 Survey Area

Locations are in Irish Transverse Mercator (ITM), Elevations are in mOD (Malin Head)



Minerex
Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Email: info@mgx.ie
Web: www.mgx.ie

CLIENT	Hydro Environmental Services Clare County Council
PROJECT	Drumcliffe Cemetery, Co. Clare Geophysical Survey
TITLE	Map 2: EM31 Ground Conductivity Contour Map

SCALE:	1:1000 @ A3
PROJECT:	6667
DRAWN:	JS
DATE:	20/12/2022
MGX FILE:	6667d_Drawings.dwg
STATUS:	Draft

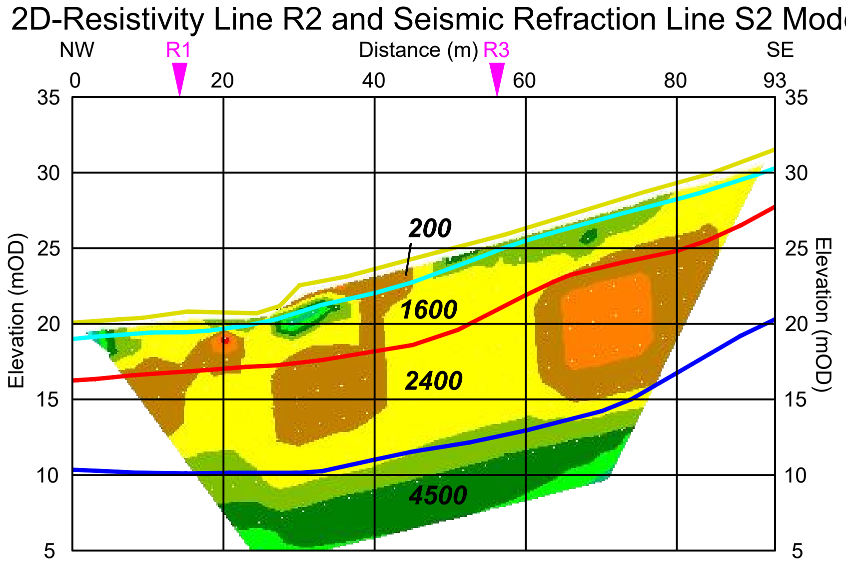
EM31 Ground Conductivity Values:

Conductivity in mS/m

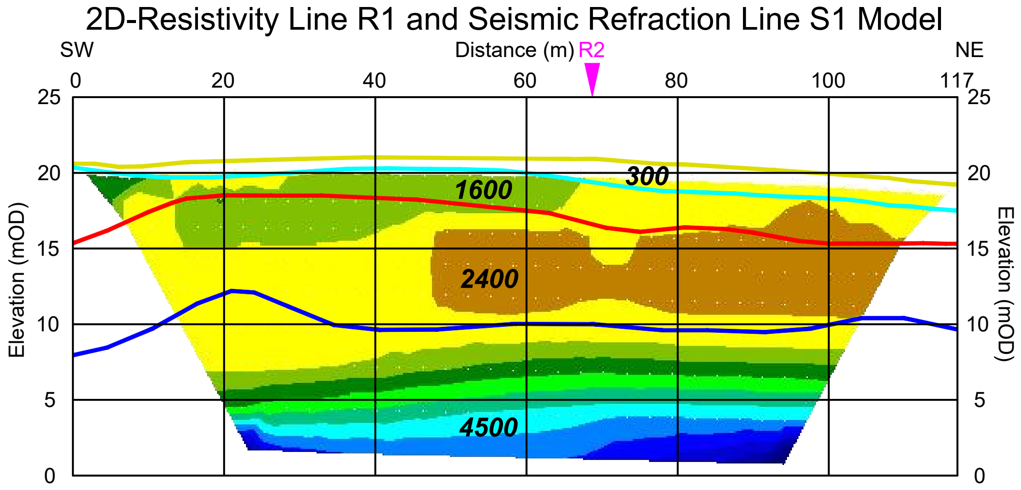
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

The map shows the EM31 ground conductivity contours in mS/m. The negative and low (blue) conductivities indicate buried metal. The middle range (green) values indicate boulder clay. The yellow NW-SE line is a former field boundary. The high (red) values indicate interference from metal objects (fences).

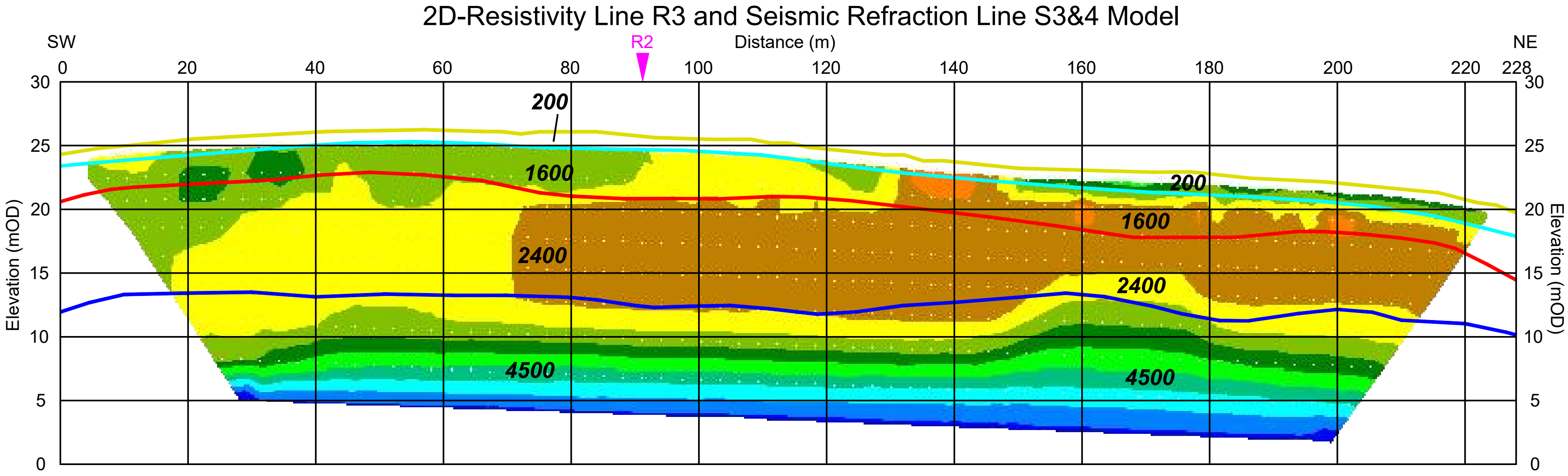
2D-Resistivity Line R2 and Seismic Refraction Line S2 Model



2D-Resistivity Line R1 and Seismic Refraction Line S1 Model



2D-Resistivity Line R3 and Seismic Refraction Line S3&4 Model

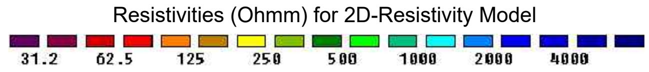


Layers from Seismic Refraction Model:

- Ground Surface/Top of Layer 1 (200 - 300 m/s)
- Top of Layer 2 (1600 m/s)
- Top of Layer 3 (2400 m/s)
- Top of Layer 4 (4500 m/s)
- ***1600*** Seismic Velocity in m/s

2D-Resistivity Model Values:

Resistivities (Ohmm) for 2D-Resistivity Model



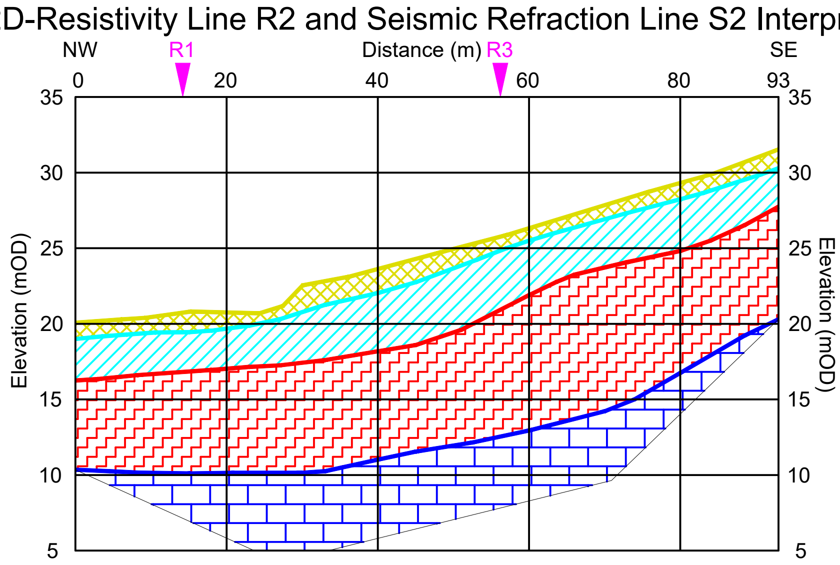
Minerex
Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare
Tel. (01) 6510030
Email: info@mgx.ie
Web: www.mgx.ie

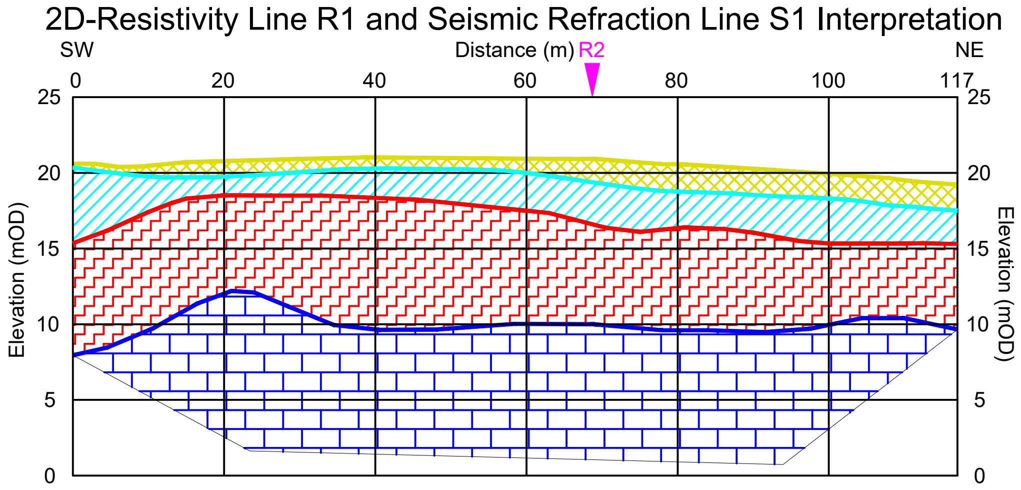
CLIENT	Hydro Environmental Services Clare County Council
PROJECT	Drumcliffe Cemetery, Co. Clare Geophysical Survey
TITLE	Figure 1: Models of Geophysical Survey

SCALE:	1:1000 @ A3, VE x 2
PROJECT:	6667
DRAWN:	JS
DATE:	20/12/2022
MGX FILE:	6667d_Drawings.dwg
STATUS:	Draft

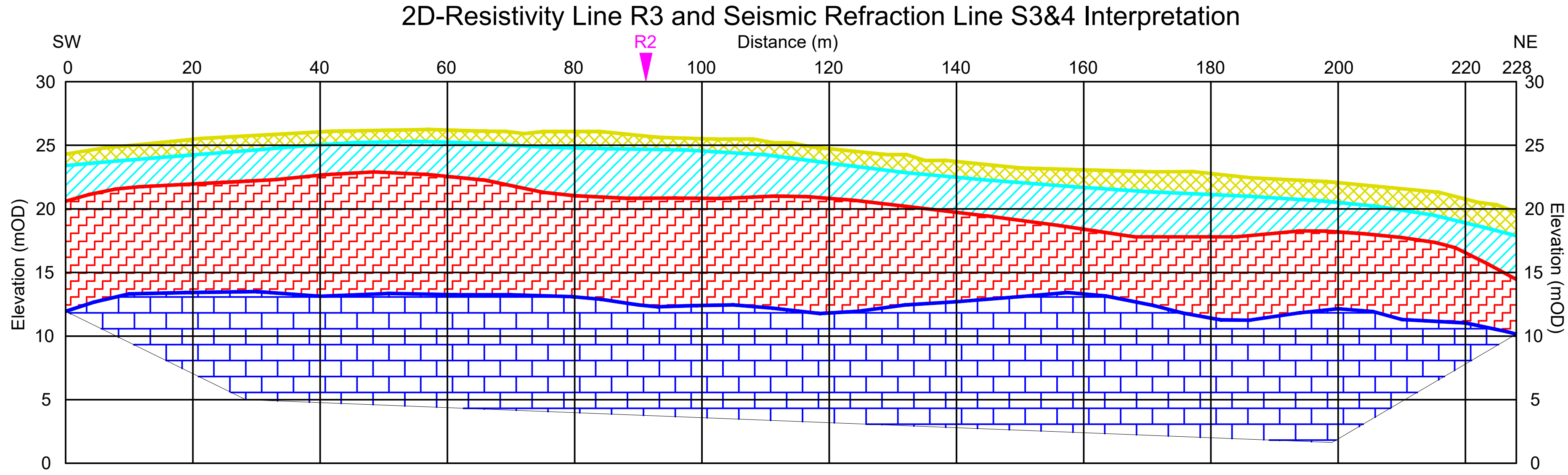
2D-Resistivity Line R2 and Seismic Refraction Line S2 Interpretation



2D-Resistivity Line R1 and Seismic Refraction Line S1 Interpretation



2D-Resistivity Line R3 and Seismic Refraction Line S3&4 Interpretation



Layers from Seismic Refraction Model:

- Ground Surface/Top of Layer 1 (200 - 300 m/s)
- Top of Layer 2 (1600 m/s)
- Top of Layer 3 (2400 m/s)
- Top of Layer 4 (4500 m/s)

Interpretation:

1 Soft or loose Soil
2 Very stiff Boulder Clay
3 Hard Boulder Clay
4 Good to very good clean Limestone

Minerex
Geophysics Limited
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PROJECT	Drumcliffe Cemetery, Co. Clare Geophysical Survey	PROJECT:	6667
		DRAWN:	JS
		DATE:	20/12/2022
TITLE	Figure 2: Interpretation of Geophysical Survey	MGX FILE:	6667d_Drawings.dwg
		STATUS:	Draft

22 Lower Main Street, Dungarvan, Co. Waterford, X35 HK11
T: +353-(0)58-441 22 **F:** +353-(0)58-442 44 **E:** info@hydroenvironmental.ie

www.hydroenvironmental.ie