Moyvannan Electricity Substation

# Environmental Impact Assessment Report

# Annex 6.1: Geophysical Investigation Report

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AGP23061_02

# Report on the Geophysical Investigation At Seven Hills Wind Farm Substation Co. Roscommon For Energia

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*THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOPHYSICS LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.*

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|---|---|---|---|
| **AUTHOR** | **CHECKED** | **REPORT STATUS** | **DATE** |
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| TONY LOMBARD M.SC (GEOPHYSICS) | | V.02 | 09TH NOVEMBER 2023 |

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## 1. EXECUTIVE SUMMARY

APEX Geophysics Limited was requested by Energia to carry out a geophysical survey at the site of the proposed Seven Hills Wind Farm substation, County Roscommon. The site is c. 8.2 ha in extents and consists of open agricultural land and topography is undulating and varies between 66.6 – 80.3 m OD.

The objectives of the survey are to provide information on the presence of any potential karst features, the thickness and type of the soil material and the depth to and the type of bedrock.

The Geological Survey of Ireland (GSI) Quaternary Sediments map for the area indicates that the site is in an area of till derived from limestone with bedrock outcrop or subcrop/Karstified bedrock in the northeast of the site. The bedrock geology map for the area indicates that the site is predominantly underlain by undifferentiated Visean Limestones with Mudbank limestone in the north of the site. The GSI karst database indicates the closest karst feature, an enclosed depression, is c. 400 m to the west of the site.

The survey was carried out between the 24$^{th}$ and 26$^{th}$ of April 2023 and involved the collection of 4 Electrical Resistivity Tomography (ERT) and 6 seismic refraction profiles. Borehole data was provided in October 2023.

The results of the investigation are shown on maps, sections and tables and are summarised in **Appendix D**.

The geophysical data generally indicates the following soil layers:

- an upper layer of loose clayey sandy gravel topsoil 0.6 m thick underlain by intermittent layers of;
- medium dense to dense silty sandy gravel/boulders 1.9 to 8.8 m thick (average 4.8 m);
- medium dense to dense to very dense clayey sand/gravel 0.5 to 10 m thick (average 7.5 m);
- stiff to very stiff sandy gravelly clay 1.0 to 8.9 m thick (average 5.0 m).

Depth to top of interpreted dolomitic limestone/limestone rock across the site ranges from 0.6 m below ground level (bgl) in the south of the site to 13.5 m bgl in the northeast. The seismic velocities and resistivity values indicate the upper 1.5 m of rock is highly weathered in places with some cavities and clay infill also present, as encountered in the boreholes. This material overlies moderately weathered to slightly weathered rock over slightly weathered to fresh rock.

Where present within proposed construction depth highly weathered rock will be rippable and underlying rock will be marginally rippable to requiring breaking/blasting.

Two main zones of rock with a potential high degree weathering/fracturing with clay infill are interpreted across the site. One deeply penetrating zone (Z1) is present in the central part of the site and direct investigation boreholes targeted this zone and encountered fractures with clay smearing, infilled cavities with sandy gravelly clay within highly weathered to slightly weathered to fresh rock. A second area of low resistivity values in the bedrock is present as a broader feature at the top of the rock at the NE of profile R4.

Where bedrock excavation is proposed, a detailed assessment of excavatability should be carried out combining the results of the geophysical survey, rotary core drilling, strength testing, and trial excavation pits down to formation level using a high-powered excavator of similar rating to that to be used during construction. A more detailed discussion of velocity and excavatability is contained in Appendix B.

The results of the geophysical investigation should be reviewed following any further direct investigation.

## 2. INTRODUCTION

APEX Geophysics Limited was requested by Energia to carry out a geophysical survey at the site of the proposed Seven Hills Wind Farm substation, County Roscommon. A geophysical investigation is required to provide information on the subs-soil conditions and potential karst features across the site.

### 2.1 Survey Objectives

The objectives of the survey are to provide information on:

- the presence of any potential karst features
- the thickness and type of the soil material
- the depth to and the type of bedrock

### 2.2 Site Background

The Seven Hills Wind Farm substation site (Fig. 2.1) is located approximately 12.5 km northwest of Athlone. The site is c. 8.2 ha in extents and consists of open agricultural land and topography is undulating and varies between 66.6 – 80.3 m OD.


*Fig 2.1: Site location shown in magenta.*

#### 2.2.1 Soils

The Geological Survey of Ireland (GSI) Quaternary Sediments map for the area (Fig. 2.2) indicates the site is in an area of till derived from limestone with bedrock outcrop or subcrop/Karstified rock in the northeast of the site.


*Fig 2.2: Quaternary sediments map.*

### 2.2.2 Geology and Karst

The GSI 1:100k Bedrock Geology map for the area (Fig. 2.3) indicates that the site is predominantly underlain by undifferentiated Visean Limestones with Mudbank limestone in the north of the site.

Several karst features, including springs, swallow holes and enclosed depressions are shown on the GSI karst database in the vicinity of the site with the closest karst feature, an enclosed depression, c. 400 m to the west of the site.


*Fig 2.3: Bedrock geology map.*

### 2.2.3 Vulnerability

The groundwater vulnerability rating for the site (Fig. 2.4) varies from high in the southwest to extreme across most of the site and rock at or near surface or karst in the northeast of the site.

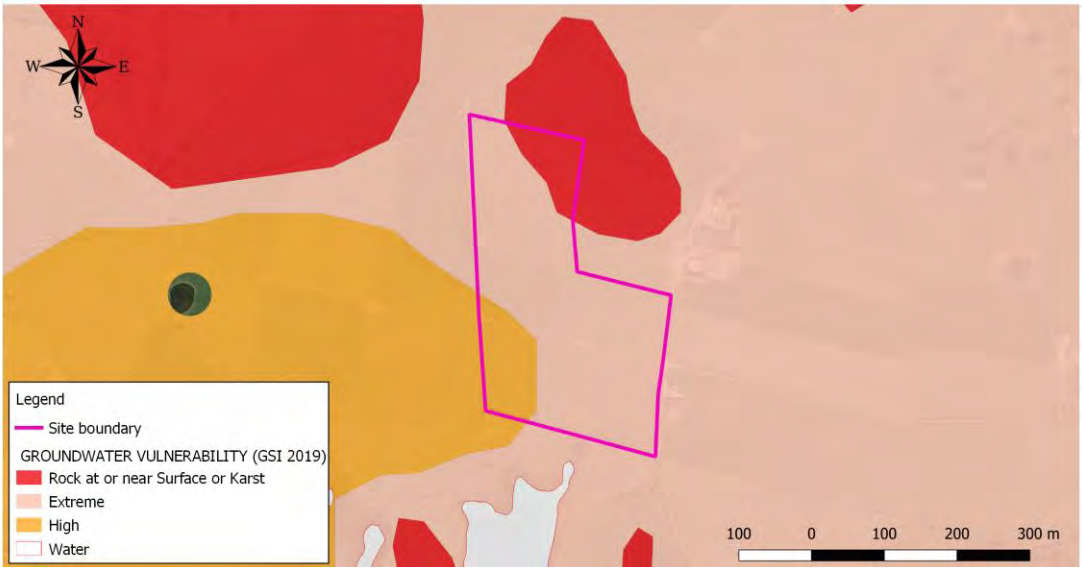


*Fig 2.4: Groundwater vulnerability map.*

### 2.2.4 Aquifer Classification

The Visean limestone is classified as a 'Regionally Important aquifer – karstified (conduit)' (GSI) and the Mudbank limestone is classified as 'Locally Important aquifer – bedrock which is moderately productive only in local zones' (Fig. 2.5).

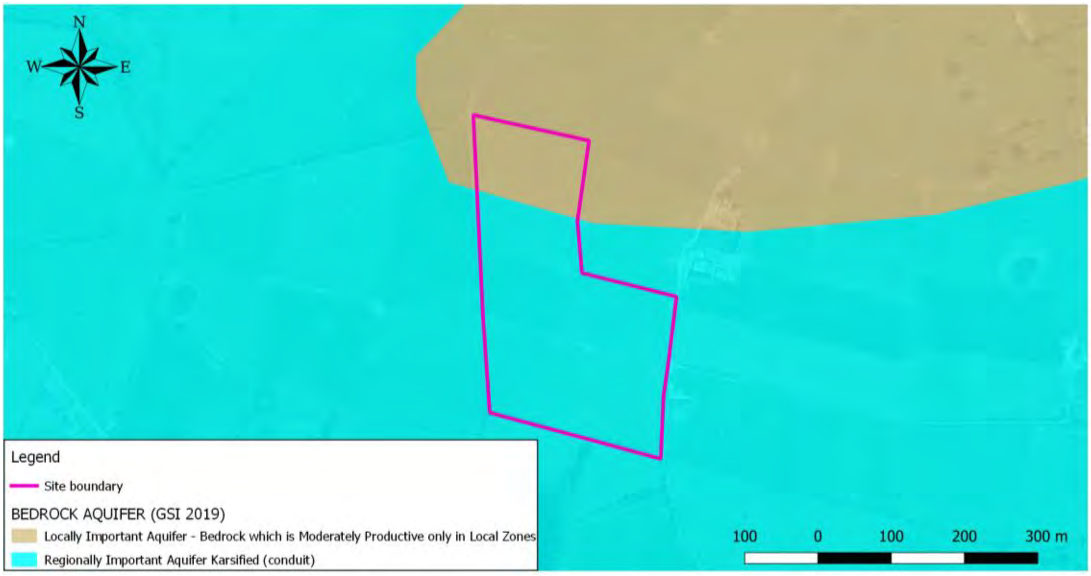


*Fig 2.5: Groundwater vulnerability map.*

## 2.2.5 Historical Data

The historical 6-inch sheet for the area (Fig. 2.6) shows ‘high ground’ across the site with a ‘grey limestone quarry’ c. 900 m to the east of the site. Areas of ‘very abruptly undulating high ground, more stone than soil, limestone broken up in situ’is shown to the to the northwest and south of the site.

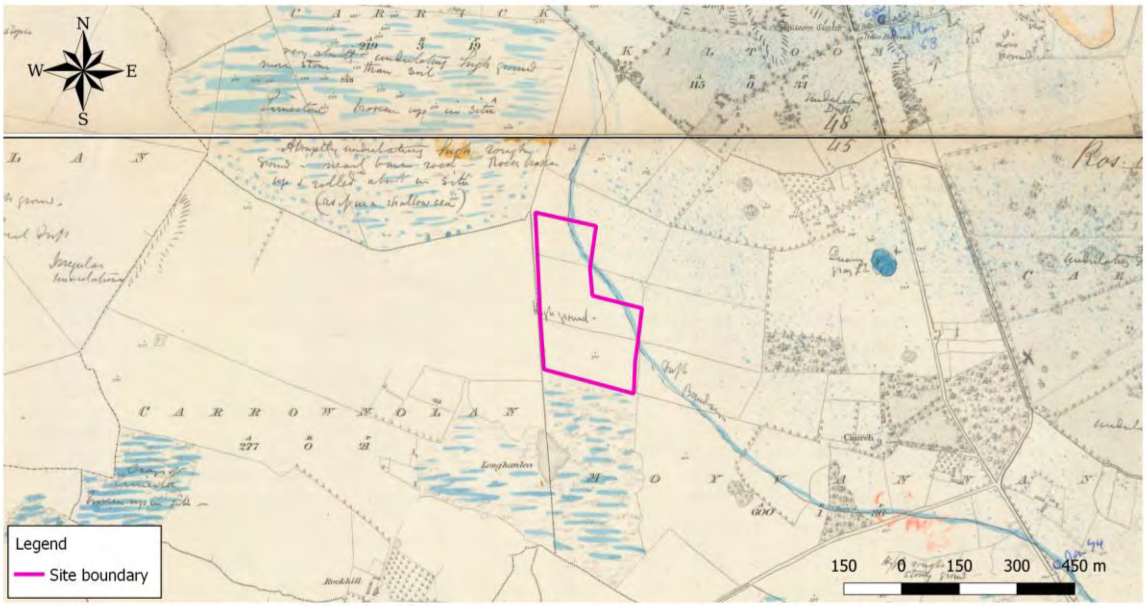


*Fig 2.6: The historical 6inch map.*

## 2.2.6 Direct Investigation Data

Information for six trial pits (TP-01 – TP-05 & soak pit TP-SA01), five cable percussion boreholes (BH01 – BH06, BH05 was not acquired) and six follow on rotary cores (RC01 – RC06) was provided in October 2023 to assist in the compilation of this report.

The trial pits were excavated to depths ranging from 0.5 to 4.1 m below ground level (bgl) where they terminated, with the exception of TP-SA01, on obstructions due to large cobbles and boulders or bedrock.

The soils generally comprised of a thin topsoil layer 0.1 to 0.4 m thick over soft to firm becoming stiff to very stiff sandy gravelly clay, some clayey gravelly sand, clayey sandy gravel and dense sandy gravel (Drillers note).

Rock was encountered at depths of 4.05 to 12.2 m bgl. To termination depths of 20.3 to 24.8 m bgl encountered rock was described as very weak to very strong highly weathered to slightly weathered to fresh dolomitic limestone with vugs and strong to very strong slightly weathered to fresh limestone. Fractures with clay smearing and infill were encountered in the rock and infilled cavities approximately 0.1 m thick with sandy gravelly clay were encountered in the dolomitic limestone. In RC04 the encountered dolomitic limestone was mostly non-intact from 10.05 to 11.6 m bgl.

The direct investigation locations are shown on the drawings in Appendix D.

## 2.3 Survey Rationale

The geophysical investigation consisted of reconnaissance EM ground conductivity mapping with follow-up Electrical Resistivity Tomography (ERT) and Seismic Refraction profiling:

**EM** ground conductivity mapping operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/metre (mS/m). This technique will provide information on the shallow (0-6m below ground level) variation of the superficial deposits and outline the extent of any shallow bedrock.

**ERT** soundings image the resistivity of the materials in the subsurface along a profile to produce a pseudo-section showing the variation in resistivity to depths dependent on the length of the profile. Each pseudo-section is interpreted to determine the material type along the profile based on the typical resistivities returned for Irish ground materials.

**Seismic Refraction Profiling** measures the P-wave velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. This method profiles the depth to the top of the stiff soils and bedrock and provides information on the quality/strength of the bedrock.

As with all geophysical methods the results are based on indirect readings of the subsurface properties. The effectiveness of the proposed approach will be affected by variations in the ground properties. By combining a number of techniques it is possible to provide a higher quality interpretation and reduce any ambiguities which may otherwise exist. Further information on the detailed methodology of each geophysical method employed in this investigation is given in **APPENDIX A: DETAILED METHODOLOGY**.

## 3. RESULTS

The survey was carried out between the 24th and 26th of April 2023. The geophysical survey locations are indicated on Drawing AGP23061_01 (Appendix D). Direct investigation data was provided in October 2023 to assist in the compilation of this updated report.

### 3.1 EM Ground Conductivity Mapping

EM ground conductivity data acquisition was commenced on site but due to a high level of EM interference good quality data could not be acquired. Following on site testing during a number of visits and in consultation with the client the survey was terminated.

### 3.2 ERT

Four resistivity profiles were recorded across the site (R1 to R4). The results are presented on Drawings AGP23061_R1 to R4.

The resistivity values across this site generally ranged from 80->10,000 Ohm-m. The resistivity values have been interpreted in conjunction with the seismic and direct investigation data as follows:

| Resistivity (Ohm-m) * | Interpretation |
|---|---|
| 80-250 | Sandy gravelly CLAY |
| 250 – 500 | Clayey sandy GRAVEL |
| 500 – 1,000 | Silty sandy GRAVEL/BOULDERS |
| 80-300 | Rock with high degree of karstification with clay/ infill |
| 300-500 | Rock with some degree of karstification/fracturing/fissuring |
| 250-500 | Weathered/Fractured dolomitc Limestone/Limestone some cavities with clay infill |
| 500-1,100 | Weathered/Fractured dolomitic Limestone/Limestone |
| 1,100-10,000 | Dolomitic Limestone/Limestone |

### 3.3 Seismic Rrefraction profiling

Six P-wave seismic refraction profiles (S1-S6) were recorded across the site. The results are included on Drawings AGP23061_R1 to R4.

The P-wave seismic velocities (Vp) have been interpreted as indicating up to 4 velocity layers as follows:

<table>
<tr><th>Layer</th><th>Velocity (m/s)</th><th>Average Velocity (m/s)</th><th>Interpretation</th><th>Estimated Stiffness/ Rock Quality</th><th>Estimated Excavatability</th></tr>
<tr><td>1</td><td>217-251</td><td>233</td><td>Soils</td><td>Soft/ Loose</td><td>Diggable</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">686-902</td><td rowspan="2">821</td><td>Soils</td><td>Firm/Medium dense</td><td>Diggable</td></tr>
<tr><td>Highly Weathered/Fractured/possible karst Bedrock</td><td>Poor</td><td>Rippable</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">1,534-2,152</td><td rowspan="2">1,763</td><td>Soils</td><td>Stiff-Very Stiff/ Dense-Very Dense</td><td>Diggable</td></tr>
<tr><td>Moderately Weathered/Fractured/possible karst Bedrock</td><td>Fair</td><td>Marginally Rippable-Break</td></tr>
<tr><td>4</td><td>2,666-5,144</td><td>3,966</td><td>Slightly Weathered to Fresh Bedrock</td><td>Good</td><td>Break/Blast</td></tr>
</table>

### 3.4 Integrated Interpretation

The interpretation of the geophysical data is plotted on Drawings AGP22223_R1-R4 and summarised on Drawing AGP22223_04.

The geophysical data generally indicates the following soil layers:

- an upper layer of loose clayey sandy gravel topsoil 0.6 m thick underlain by intermittent layers of;
- medium dense to dense silty sandy gravel/boulders 1.9 to 8.8 m thick (average 4.8 m);
- medium dense to dense to very dense clayey sand/gravel 0.5 to 10 m thick (average 7.5 m);
- stiff to very stiff sandy gravelly clay 1.0 to 8.9 m thick (average 5.0 m).

The stiff to very stiff sandy gravelly clay layer may act as a founding layer and an aquitard. This material is mainly present in the east and northeast of the site and is summarised on Drawing AGP23061_04.

The seismic velocities indicate some weathered rock may be present towards the base of the soil.

Depth to top of interpreted dolomitic limestone/limestone rock across the site is shown on Drawing AGP23061_02 and ranges from 0.6 m in the south of the site (see Drawing AGP23061_R3) to 13.5 m bgl in the northeast (see Drawing AGP23061_R2). The average depth across the site is 6.0 m bgl.

While the GSI Quaternary Sediments map (Fig 2.2) shows bedrock/outcrop in the far northeast of the site the depth to top of interpreted dolomitic limestone/limestone map indicates a localised increase to > 8 m bgl just to the south. Boreholes BH01/RC01, BH02/RC02 and BH03/RC03 in the north of the site encountered rock at 12.2 m, 6.35 m and 10.9 m bgl respectively and this information was used in compilation of the depth to rock map.

Interpreted rock elevation is shown on Drawing AGP23061_03 and ranges from 57.0 m OD in the southeast of the site to 71.5 m OD in the west and northwest of the site.

The seismic velocities and resistivity values indicate the upper 1.5 m of rock is highly weathered in places with some cavities and clay infill also present, as encountered in the boreholes. This material overlies moderately weathered to slightly weathered rock over slightly weathered to fresh rock.

Where present within proposed construction depth highly weathered rock will be rippable and underlying rock will be marginally rippable to requiring breaking/blasting.

On all four ERT profiles areas of slightly decreased resistivity values (< 1,100 Ohm) within the bedrock indicate areas of increased thickness of the moderately to slightly weathered limestone (see Drawings AGP23061_R1 to AGP23061_R4).

Karst features are not indicated in the area of interpreted shallow moderately to slightly weathered to fresh rock in the south of the site (see Drawing AGP23061_02). This area may be suitable for the footprint of the proposed construction, and this should be assessed upon completion of all direct investigations.

**Note:** The maps displayed on Drawings AGP23061_02 and AGP23061_03 are based on interpolation and extrapolation between discrete data points and should be used accordingly.

### 3.4.1 Karst

Two main zones of rock with a potential high degree of karstification with clay infill are interpreted across the site. One deeply penetrating zone (Z1) is present in the central part of the site and is characterised by an area of low resistivity values (< 300 Ohm-m) in the bedrock at a distance of 165 m on profile R2 and 145 m on profile R4 (see Drawings AGP23061_02 and AGP23061_03). This zone is interpreted as a WSW – ENE feature shown on Drawing AGP23061_04 summary map. Borehole BH05/RC05 targeted this zone and encountered fractures with clay smearing, infilled cavities with sandy gravelly clay within highly weathered to slightly weathered to fresh rock over a depth range of 8.65 to 20.3 m bgl (see Drawing AGP23061_R2).

A second area of low resistivity values in the bedrock is present as a broader feature at the top of the rock at the NE of profile R4. This feature (Z2) penetrates to 22 m bgl.

## 4. RECOMMEDATIONS

Any changes in surface water drainage or groundwater levels associated with proposed construction activities may re-activate dormant karst features and cause subsidence of the overburden materials.

In order to minimize the risk of subsidence all drains should be sealed and surface water disposed of away from the construction area. Any cavities exposed during stripping of topsoil or excavation of rock should be backfilled in the appropriate manner for karstified limestone areas as advised by a competent geotechnical engineer.

Where bedrock excavation is proposed, a detailed assessment of excavatability should be carried out combining the results of the geophysical survey, rotary core drilling, strength testing, and trial excavation pits down to formation level using a high-powered excavator of similar rating to that to be used during construction. A more detailed discussion of velocity and excavatability is contained in Appendix B.

The results of the geophysical investigation should be reviewed based on the findings of any direct investigation.

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## APPENDIX A: DETAILED GEOPHYSICAL METHODOLOGY

A combination of geophysical techniques was used to provide a high quality interpretation and reduce any ambiguities, which may otherwise exist.

## Electrical Resistivity Tomography (ERT)

Electrical Resistivity Tomography was carried out to provide information on lateral variations in the overburden material as well as on the underlying overburden and bedrock.

**Principles**
This surveying technique makes use of the Gradient resistivity array. The 2D-resistivity profiling method records a large number of resistivity readings in order to map lateral and vertical changes in material types. This method involves the use of electrodes connected to a resistivity meter, using computer software to control the process of data collection and storage.

**Data Collection**
The ERT profiles were recorded using an Abem resistivity meter in roll-along mode, four 21 takeout multicore cables and up to 64 stainless steel electrodes. Saline solution was used at the electrode/ground interface in order to gain a good electrical contact required for the technique to work effectively. The recorded data were processed and viewed immediately after surveying.

**Data Processing**
The field readings were stored in computer files and inverted using the RES2DINV package (Geotomo Software, 2006) with up to 5 iterations of the measured data carried out for each profile to obtain a 2D-depth model of the resistivities.

The inverted 2D resistivity models and corresponding interpreted geology are displayed on the accompanying drawings alongside the processed seismic sections. Profiles have been contoured using the same contour intervals and colour codes. Distance is indicated along the horizontal axis of the profiles.

## Seismic Refraction Profiling

**Principles**
This method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities.

Seismic profiling measures the p-wave velocity (Vp) of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher Vp velocities while soft, loose or fractured materials have lower Vp velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

**Data Collection**
A Geode high resolution 24 channel digital seismograph, 24 10HZ vertical geophones and a 10 kg hammer were used to provide first break information, with a 24 take-out cable. Equipment was carried and operated by a two-person crew.

Readings are taken using geophones connected via multi-core cable to a seismograph. The depth of resolution of soil/bedrock boundaries is determined by the length of the seismic spread, typically the depth of resolution is about one third the length of the profile.( eg. 69m profile ~23m depth, 33m profile ~ 11m depth).

**Data Processing**
First break picking in digital format was carried out using the SeisImager/2D PICKWIN software program from Geometrics to construct p-wave (Vp) traveltime plots for each spread. The processing and interpretation uses the ray-tracing and tomographic inversion methods, to acquire depths to boundaries and the P-wave velocities of these layers, using the SeisImager/2D PLOTREFA program.

SeisImager/2D interprets seismic refraction data as a laterally varying layered earth structure. The program includes three methods for data analysis, time-term inversion, the reciprocal method and tomography.

The tomography method creates an initial velocity model, then traces rays through the model, comparing the calculated and measured traveltimes. The model is then modified and the process repeated to minimise the difference between the calculated and measured times. The data was processed using this method and was then converted to a layer model for display and interpretation.

Approximate errors for Vp velocities are estimated to be +/- 10%. Errors for the calculated layer thicknesses are of the order of +/-20%. Possible errors due to the "hidden layer" and "velocity inversion" effects may also occur (Soske, 1959).

## Spatial Relocation

All the geophysical investigation locations were acquired using a Trimble Geo 7X high-accuracy GNSS handheld system using the settings listed below. This system allows collection of GPS data with c.20mm accuracy.

| | |
|---|---|
| **Coordinate zone:** | Irish Transverse Mercator (ITM) |
| **Datum:** | Ordnance |
| **Coordinate units:** | Metres |
| **Altitude units:** | Metres |
| **Survey altitude reference:** | MSL |
| **Geoid model:** | Republic of Ireland |

## APPENDIX B: SEISMIC REFRACTION TOMOGRAPHIC DATA

The seismic refraction tomographic plates are shown below.

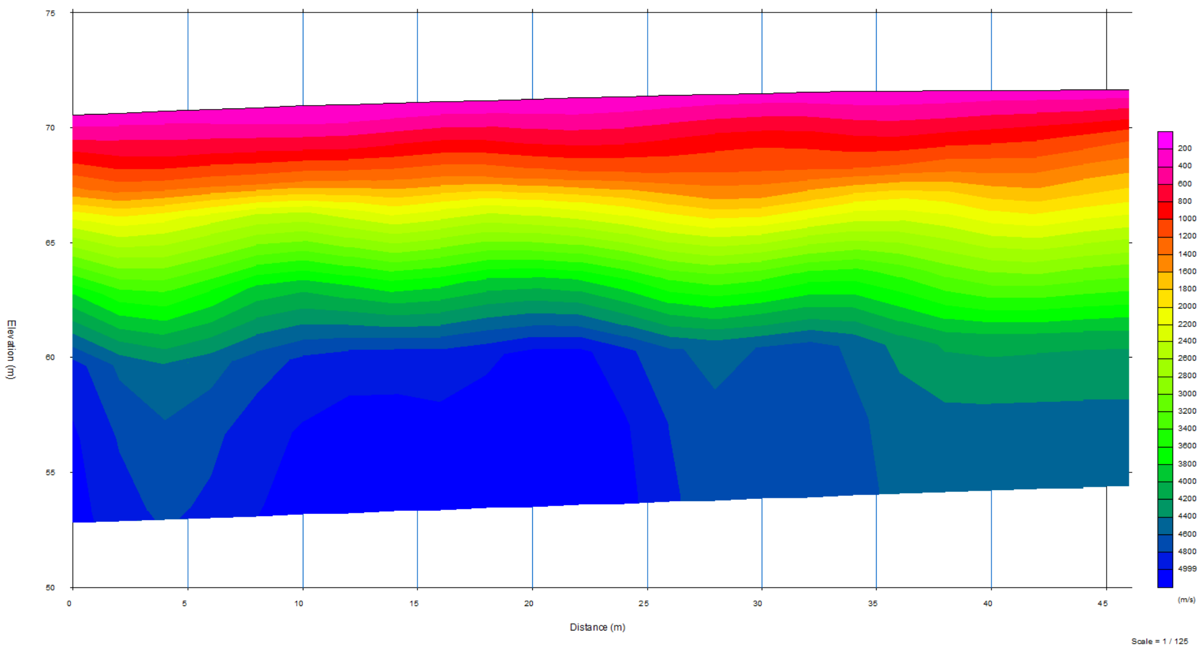



*Fig B.1: Tomographic inversion for S1, plotted SW-NE.*

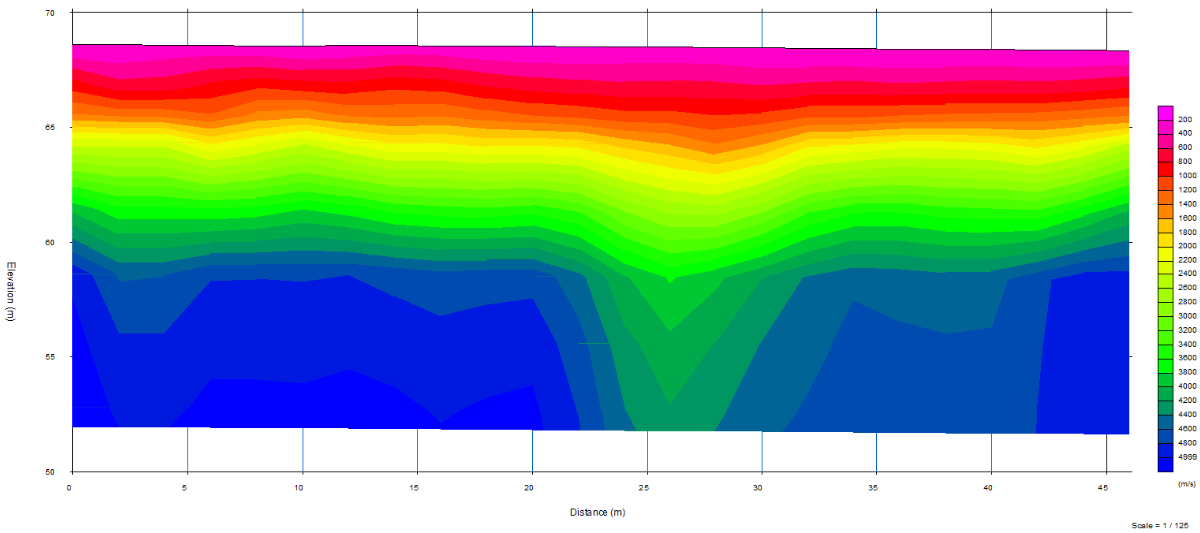



*Fig B.2: Tomographic inversion for S2, plotted SE-NW.*

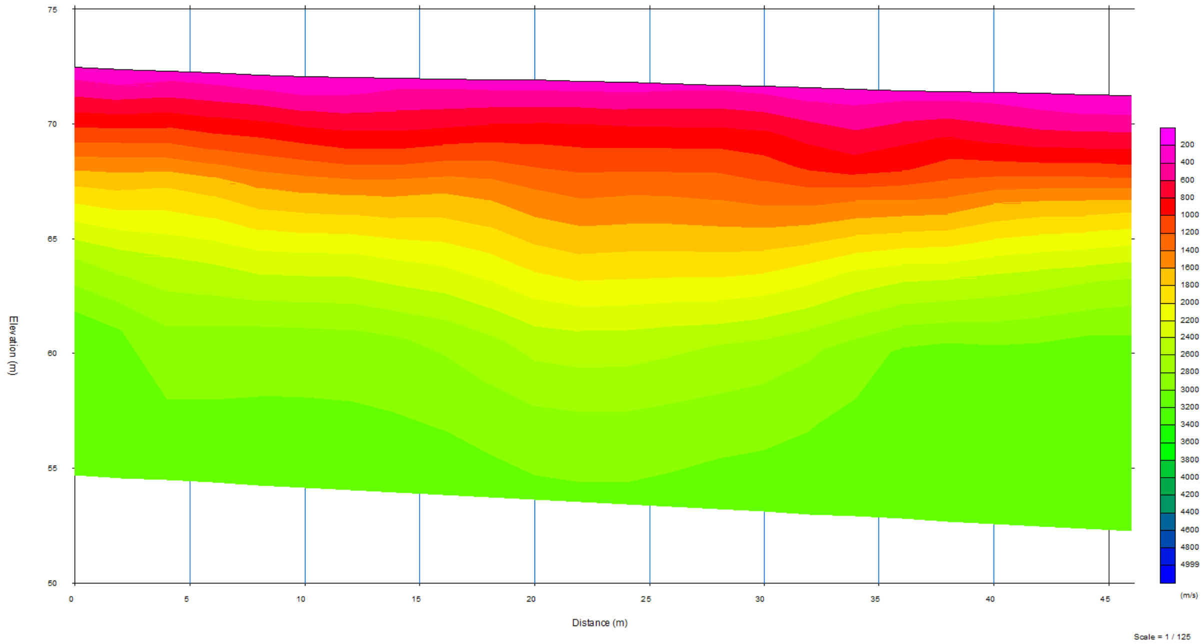



*Fig B.3 Tomographic inversion for S3, plotted NW-SE.*

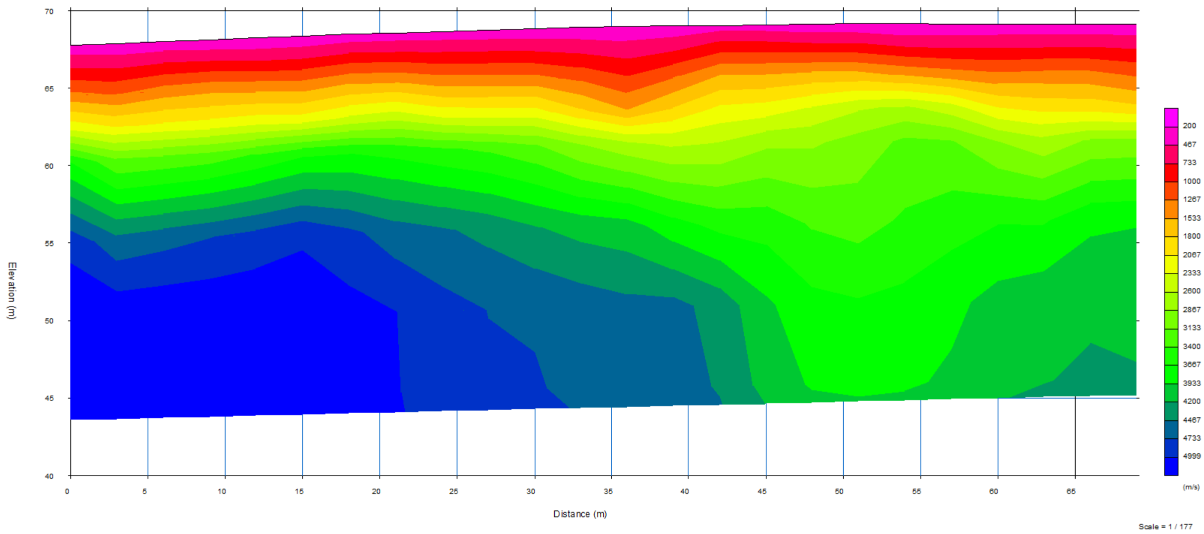



*Fig B.4: Tomographic inversion for S4, plotted SE-NW.*

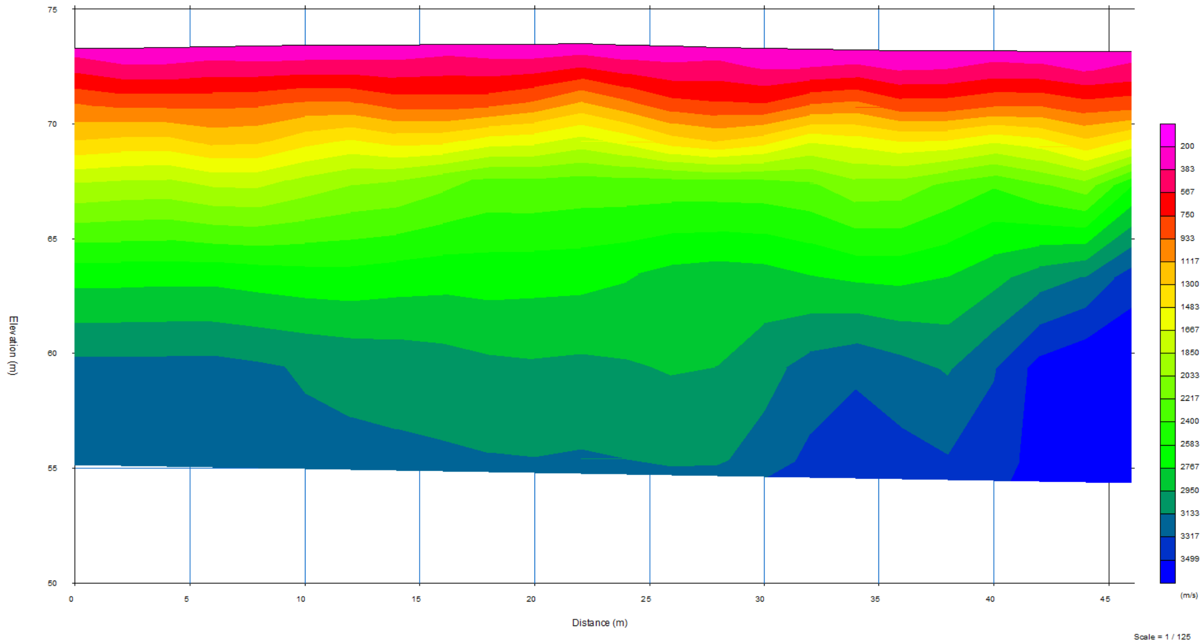



*Fig B.5: Tomographic inversion for S5, plotted NW-SE.*

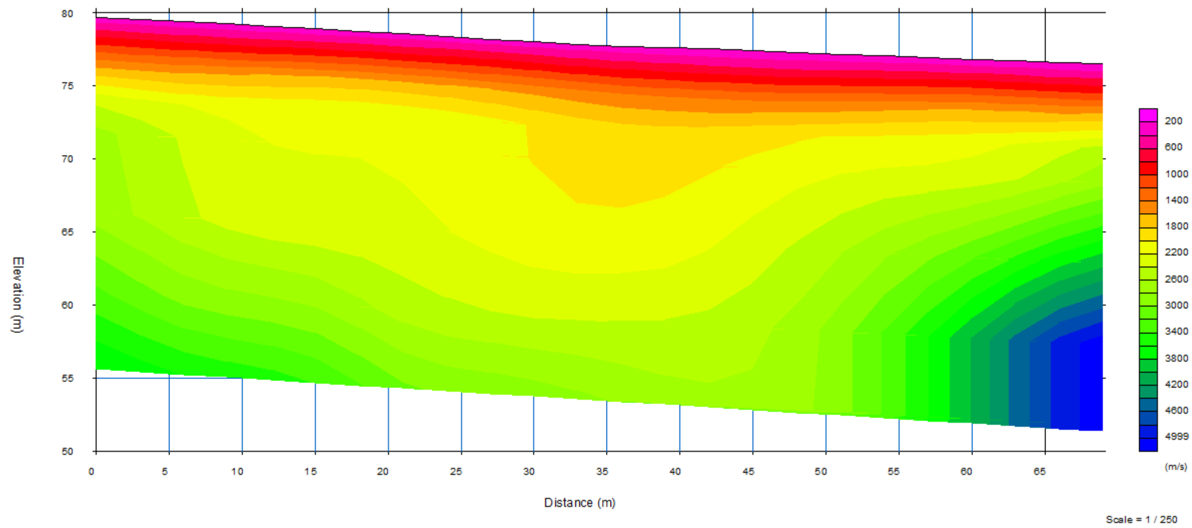



*Fig B.6: Tomographic inversion for S6, plotted NE-SW.*

## APPENDIX C: EXCAVATABILITY

The seismic velocity of a rock formation is related to characteristics of the rock mass which include rock hardness and strength, degree of weathering and discontinuities. Usually the velocity is just one of several parameters used in the assessment of excavatability. The excavatability of a rock formation is favoured by the following factors:

- Open fractures, faults and other planes of weakness of any kind
- Weathering
- Brittleness and crystalline nature
- High degree of stratification or lamination
- Large grain size
- Low compressive strength

Weaver (1975) presented a comprehensive rippability rating chart (Fig.1) in which the p-wave velocity value and the relevant geological factors could be entered and assigned appropriate weightings. The total weighted index was found to correlate very well with actual rippability.

*Fig.1 Rippability Rating Chart*

| Rock class | I | II | III | IV | V |
|---|---|---|---|---|---|
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |
| Seismic velocity (m/s) | >2150 | 2150-1850 | 1850-1500 | 1500-1200 | 1200-450 |
| Rating | 26 | 24 | 20 | 12 | 5 |
| Rock hardness | Extremely hard rock | Very hard rock | Hard rock | Soft rock | Very soft rock |
| Rating | 10 | 5 | 2 | 1 | 0 |
| Rock weathering | Unweathered | Slightly weathered | Weathered | Highly weathered | Completely weathered |
| Rating | 9 | 7 | 5 | 3 | 1 |
| Joint spacing (mm) | >3000 | 3000-1000 | 1000-300 | 300-50 | <50 |
| Rating | 30 | 25 | 20 | 10 | 5 |
| Joint continuity | Non continuous | Slightly continuous | Continuous- no gouge | Continuous- some gouge | Continuous- with gouge |
| Rating | 5 | 5 | 3 | 0 | 0 |
| Joint gouge | No separation | Slight separation | Separation <1mm | Gouge <5mm | Gouge >5mm |
| Rating | 5 | 5 | 4 | 3 | 1 |
| Strike and dip orientation | Very unfavourable | Unfavourable | Slightly unfavourable | Favourable | Very favourable |
| Rating | 15 | 13 | 10 | 5 | 3 |
| Total rating | 100-90 | 90-70* | 70-50 | 50-25 | <25 |
| Rippability assessment | Blasting | Extremely hard ripping and blasting | Very hard ripping | Hard ripping | Easy ripping |
| Tractor horsepower | | 770/385 | 385/270 | 270/180 | 180 |
| Tractor kilowatts | | 575/290 | 290/200 | 200/135 | 135 |

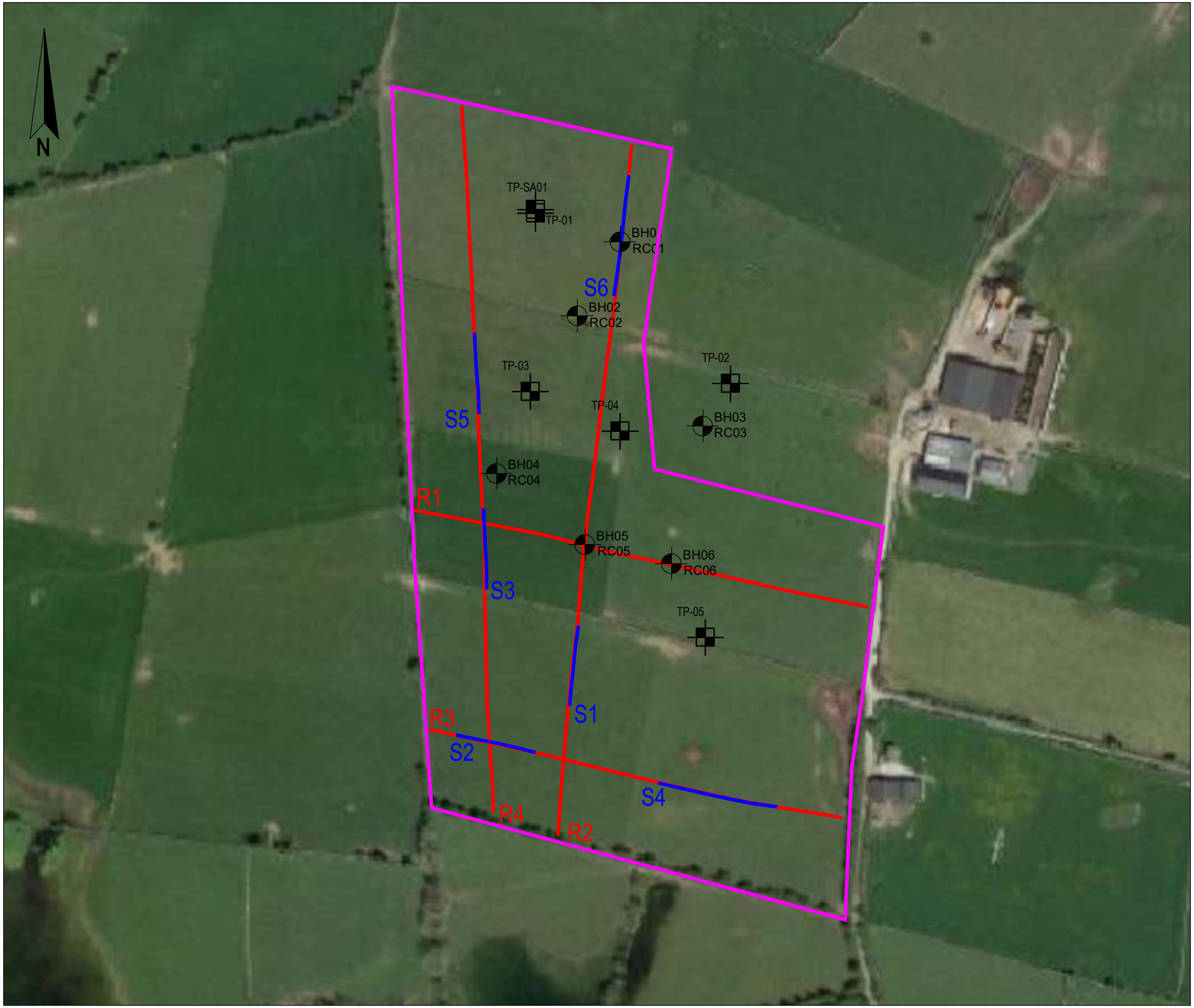
## APPENDIX D: DRAWINGS

The information derived from the geophysical is presented in the following drawings:

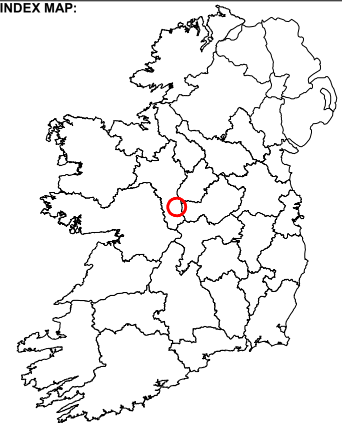
| | | |
|---|---|---|
| AGP23061_01 | Geophysical Survey Locations | 1:3000 @A3 |
| AGP23061_02 | Interpreted Depth to Rock (m BGL) | 1:3000 @A3 |
| AGP23061_03 | Interpreted Rock Elevation (m OD) | 1:3000 @A3 |
| AGP23061_04 | Summary Interpretation | 1:3000 @ A3 |
| AGP23061_R1 | Fig. 1 Results ERT R1 | 1:1000 @ A3 |
| | Fig. 2 Interpretation ERT R1 | 1:1000 @ A3 |
| AGP23061_R2 | Fig. 1 Results ERT R2 & seismic refraction S1 & S6 | 1:1250 @ A3 |
| | Fig. 2 Interpretation ERT R2 & seismic refraction S1 & S6 | 1:1250 @ A3 |
| AGP23061_R3 | Fig. 1 Results ERT R3 & seismic refraction S2 & S4 | 1:1000 @ A3 |
| | Fig. 2 Interpretation ERT R3 & seismic refraction S2 & S4 | 1:1000 @ A3 |
| AGP23061_R4 | Fig. 1 Results ERT R4 & seismic refraction S3 & S5 | 1:1250 @ A3 |
| | Fig. 2 Interpretation ERT R4 & seismic refraction S3 & S5 | 1:1250 @ A3 |

GEOPHYSICAL SURVEY LOCATIONS

SCALE 1:3000




INDEX MAP:



LEGEND:

- Site
- R1 — 2D resistivity profile
- S1 — Seismic refraction profile
- TP-01 — Trial Pit
- BH01/RC01 — Borehole/Rotary Core

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| CLIENT.: | ENERGIA |
| DRAWING NO: | AGP23061_01 |
| SCALE: | AS INDICATED @ A4 |
| DATE: | 09-11-2023 |

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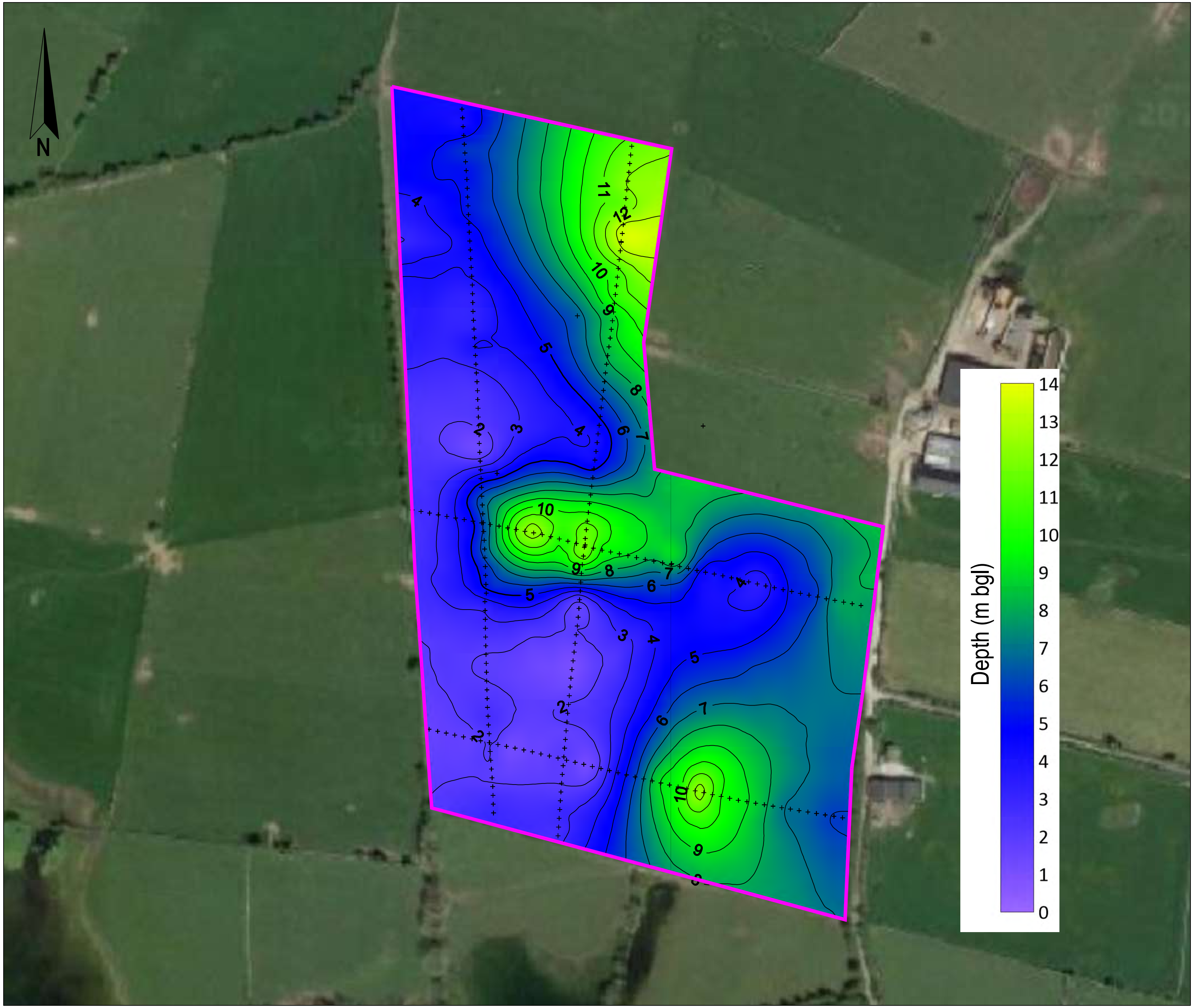
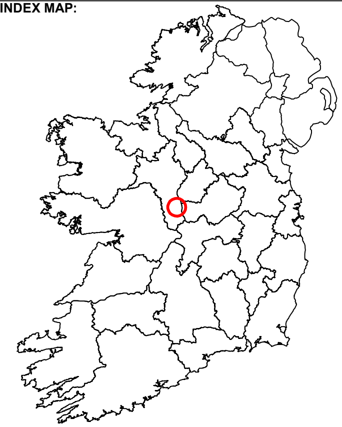
| | | | |

INTERPRETED DEPTH TO ROCK (m BGL)

SCALE 1:3000




INDEX MAP:



LEGEND:

Site

Data Point

Note:
The maps displayed here are based on interpolation between discrete data points and should be used accordingly.

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| DRAWING NO: | AGP23061_02 |
| SCALE: | AS INDICATED @ A4 |
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| 01 | 19-06-2023 | SC | TL |
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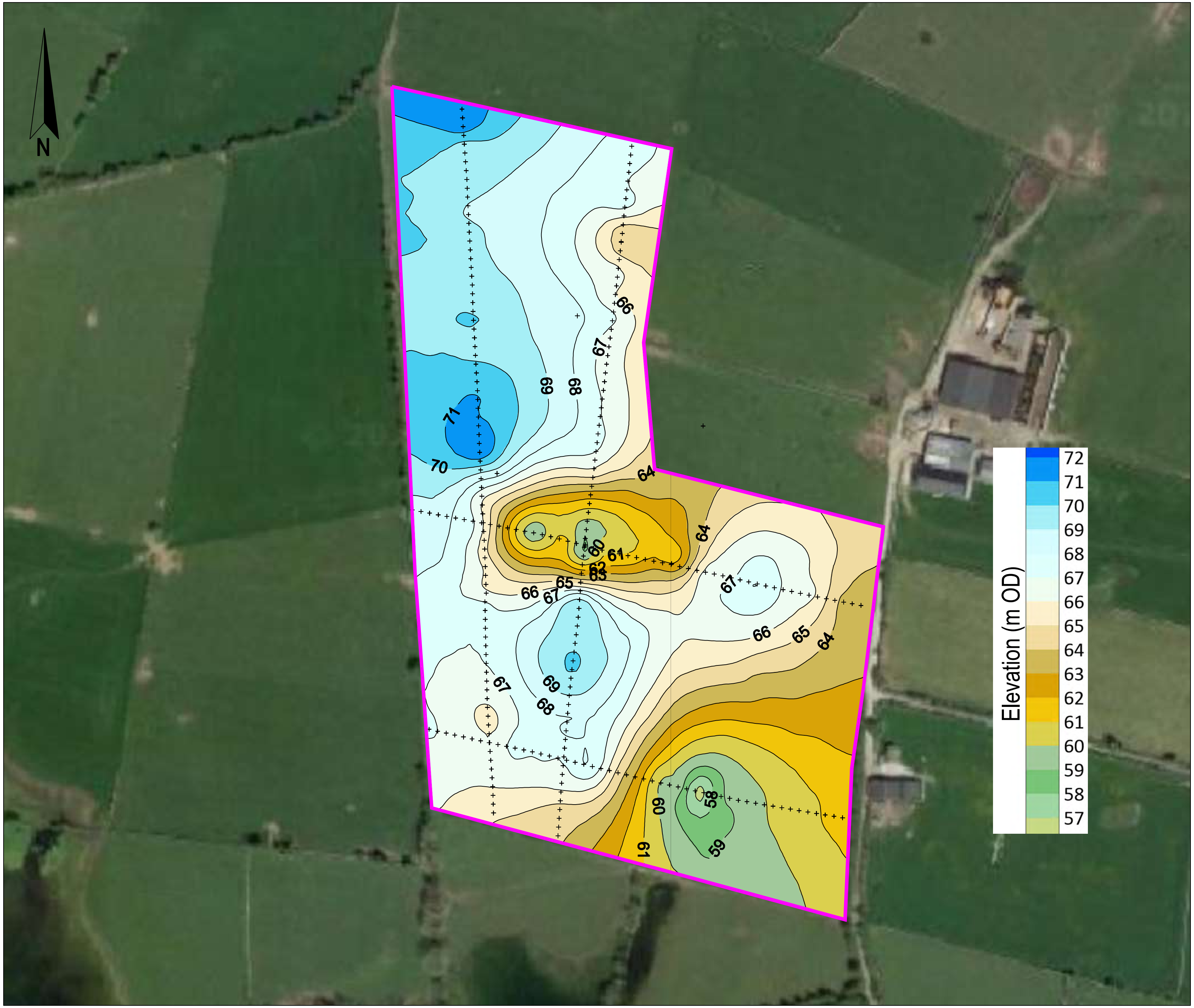
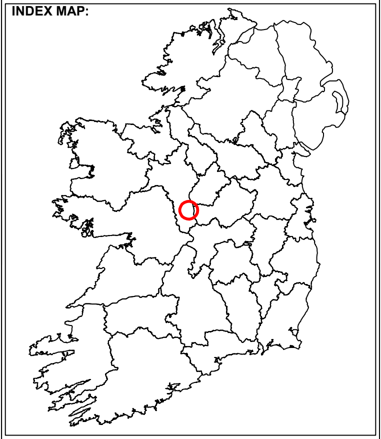
INTERPRETED ROCK ELEVATION (m OD)

SCALE 1:3000




INDEX MAP:



LEGEND:

- Site
- Data Point

Note:
The maps displayed here are based on interpolation between discrete data points and should be used accordingly.

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| CLIENT.: | ENERGIA |
| DRAWING NO: | AGP23061_03 |
| SCALE: | AS INDICATED @ A4 |
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| Version: | Date: | Drawn By: | Checked: |
|---|---|---|---|
| 01 | 19-06-2023 | SC | TL |
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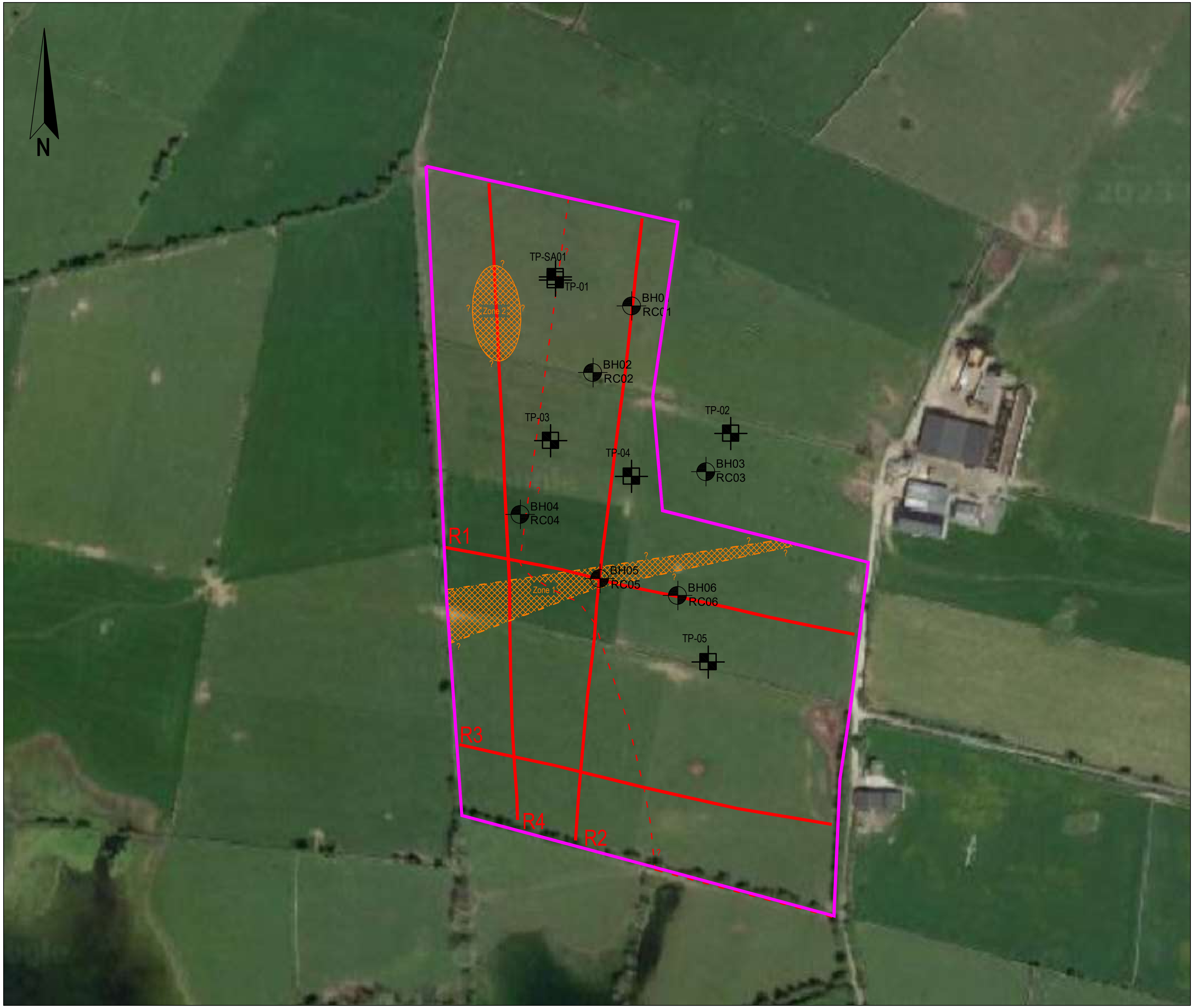
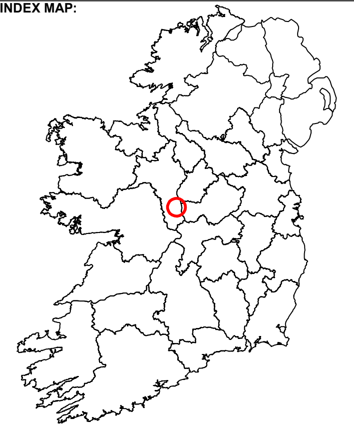
SUMMARY MAP

SCALE 1:3000




INDEX MAP:



LEGEND:

- Site
- TP-01 Trial Pit
- BH01/RC01 Borehole/Rotary Core
- Interpreted karst zones Z1 & Z2
- Main area of sandy gravelly Clay/ clayey sandy GRAVEL over rock
- ? Extension unclear

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| CLIENT.: | ENERGIA |
| DRAWING NO: | AGP23061_04 |
| SCALE: | AS INDICATED @ A4 |
| DATE: | 09-11-2023 |

| Version: | Date: | Drawn By: | Checked: |
|---|---|---|---|
| 01 | 19-06-2023 | SC | TL |
| 02 | 09-11-2023 | SC | TL |
| | | | |

FIG.1. RESULTS ERT R1

SCALE 1:1000

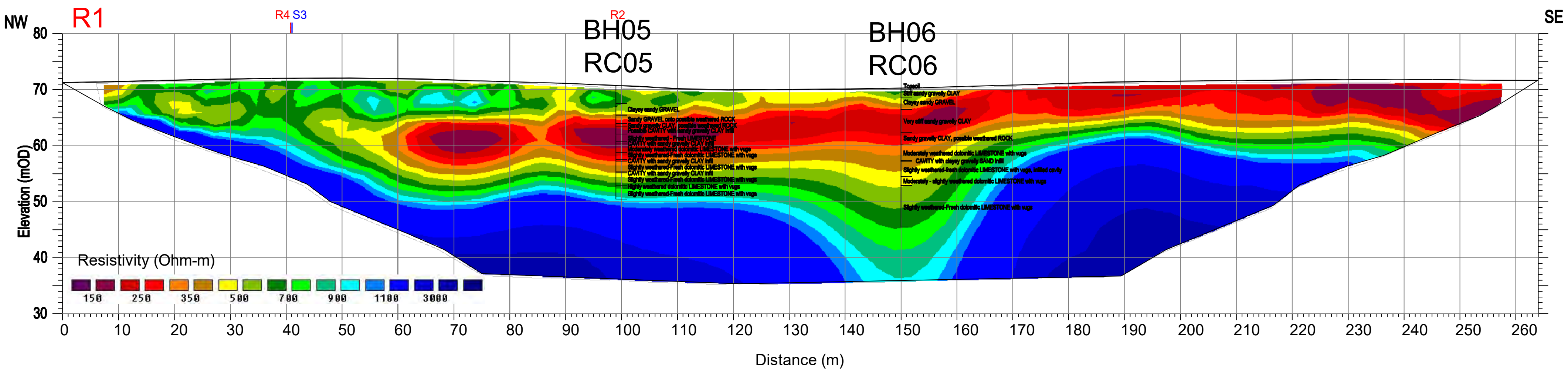
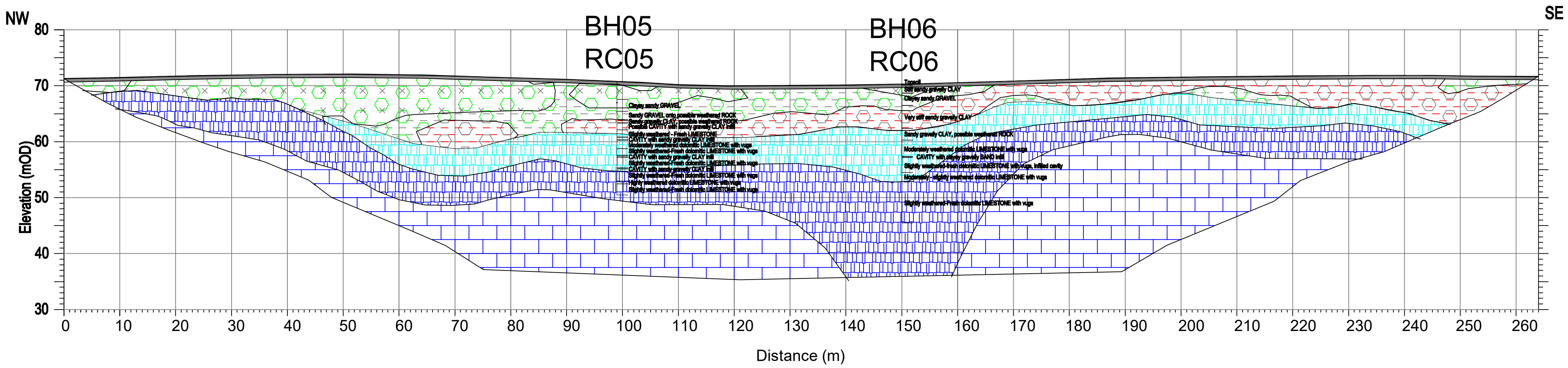



FIG.2.INTERPRETATION ERT R1

SCALE 1:1000




INDEX MAP:


**LEGEND:** interpreted P-wave velocity

- Seismic refraction layer with interpreted P-wave velocity
- Soft/Loose TOPSOIL
- Stiff-very stiff Sandy Gravelly CLAY (possible weathered rock towards base)
- Medium Dense-Dense Clayey Sandy GRAVEL (possible weathered rock towards base)
- Medium Dense-Dense Silty Sandy GRAVEL/BOULDERS (possible weathered rock towards base)
- Rock with high degree of Karstification with clay infill
- Rock with some degree of karstification/fracturing/fissuring
- Highly - moderately weathered Dolomitic LIMESTONE/LIMESTONE
- Highly - moderately weathered Dolomitic LIMESTONE /LIMESTONE some cavities and clay infill
- Moderately - Slightly Weathered Dolomitic LIMESTONE /LIMESTONE
- Slightly weathered - fresh Dolomitic LIMESTONE /LIMESTONE

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| CLIENT: | ENERGIA |
| DRAWING NO: | AGP23061_R1 |
| SCALE: | AS INDICATED @ A3 |
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|---|---|---|---|
| 01 | 19-06-2023 | SC | TL |
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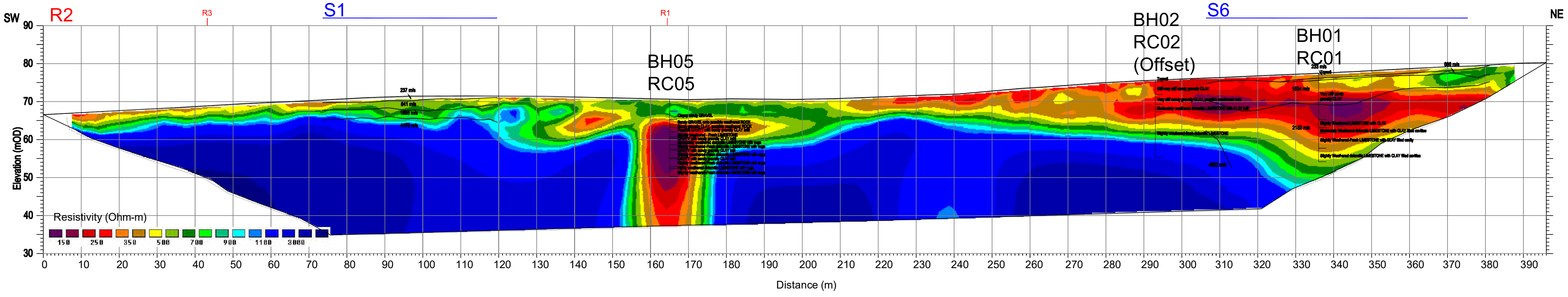
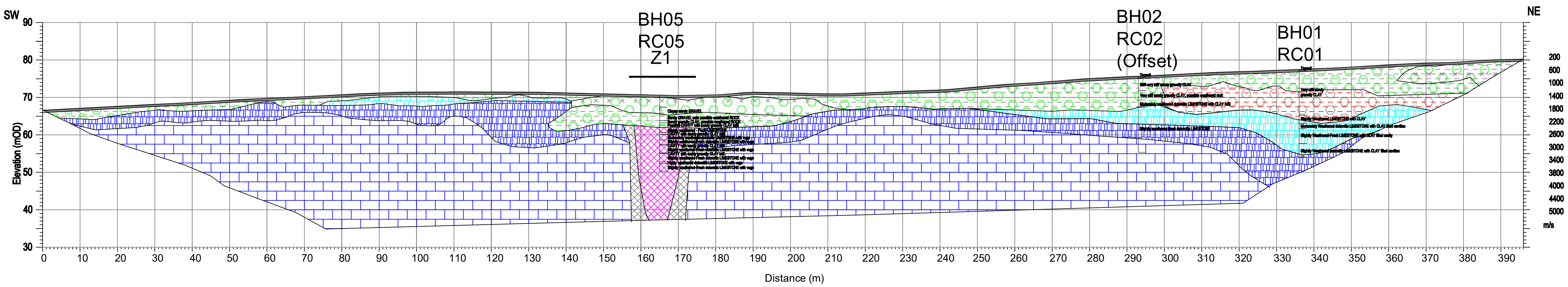
## FIG.1. RESULTS ERT R2 AND SEISMIC REFRACTION S1 & S6

SCALE 1:1250




## FIG.2.INTERPRETATION ERT R2 AND SEISMIC REFRACTION S1 & S6

SCALE 1:1250





**LEGEND:** interpreted P-wave velocity

- Seismic refraction layer with interpreted P-wave velocity
- Soft/Loose TOPSOIL
- Stiff-very stiff Sandy Gravelly CLAY (possible weathered rock towards base)
- Medium Dense-Dense Clayey Sandy GRAVEL (possible weathered rock towards base)
- Medium Dense-Dense Silty Sandy GRAVEL/BOULDERS (possible weathered rock towards base)
- Rock with high degree of Karstification with clay infill
- Rock with some degree of karstification/fracturing/fissuring
- Highly - moderately weathered Dolomitic LIMESTONE/LIMESTONE
- Highly - moderately weathered Dolomitic LIMESTONE /LIMESTONE some cavities and clay infill
- Moderately - Slightly Weathered Dolomitic LIMESTONE /LIMESTONE
- Slightly weathered - fresh Dolomitic LIMESTONE /LIMESTONE

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| CLIENT: | ENERGIA |
| DRAWING NO: | AGP23061_R2 |
| SCALE: | AS INDICATED @ A3 |
| DATE: | 19-06-2023 |

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|---|---|---|---|
| 01 | 09-11-2023 | SC | TL |
| 02 | 09-11-2023 | SC | TL |

FIG.1. RESULTS ERT R3 AND SEISMIC REFRACTION S2 & S4

SCALE 1:1000

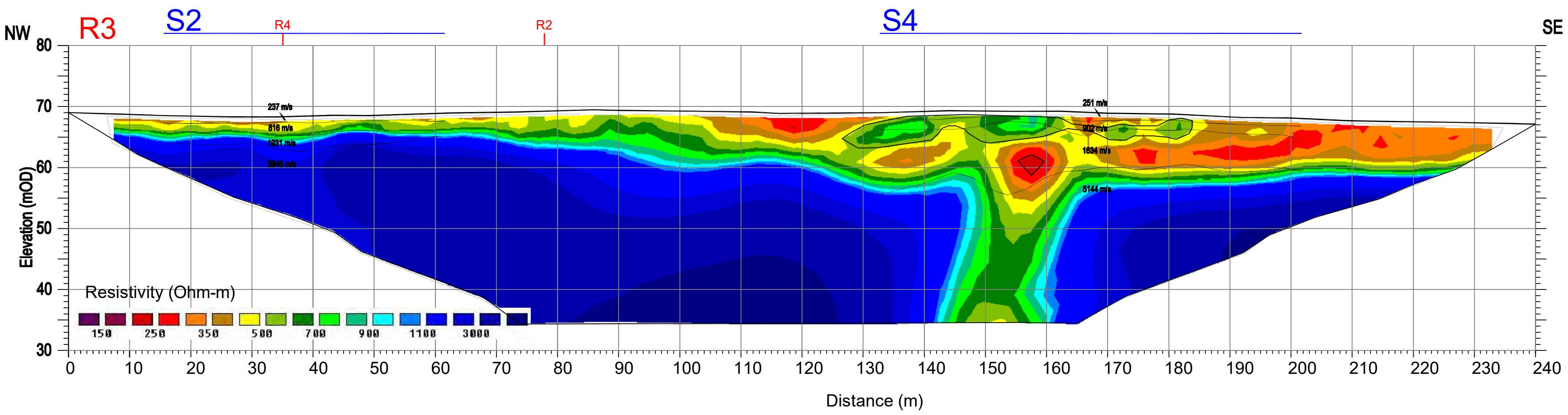
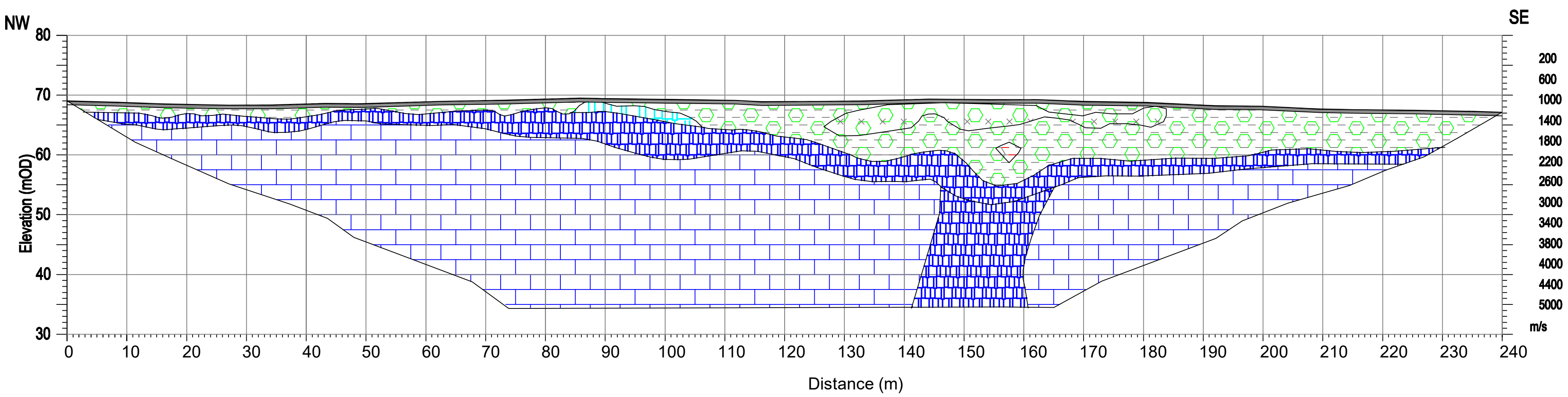



FIG.2.INTERPRETATION ERT R3 AND SEISMIC REFRACTION S2 & S4

SCALE 1:1000




INDEX MAP:


**LEGEND:** interpreted P-wave velocity

- 1254-1288 m/s — Seismic refraction layer with interpreted P-wave velocity
- Soft/Loose TOPSOIL
- Stiff-very stiff Sandy Gravelly CLAY (possible weathered rock towards base)
- Medium Dense-Dense Clayey Sandy GRAVEL (possible weathered rock towards base)
- Medium Dense-Dense Silty Sandy GRAVEL/BOULDERS (possible weathered rock towards base)
- Rock with high degree of Karstification with clay infill
- Rock with some degree of karstification/fracturing/fissuring
- Highly - moderately weathered Dolomitic LIMESTONE/LIMESTONE
- Highly - moderately weathered Dolomitic LIMESTONE /LIMESTONE some cavities and clay infill
- Moderately - Slightly Weathered Dolomitic LIMESTONE /LIMESTONE
- Slightly weathered - fresh Dolomitic LIMESTONE /LIMESTONE

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CLIENT.: ENERGIA

DRAWING NO: AGP23061_R3

SCALE: AS INDICATED @ A3

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FIG.1. RESULTS ERT R4 AND SEISMIC REFRACTION S3 & S5

SCALE 1:1250

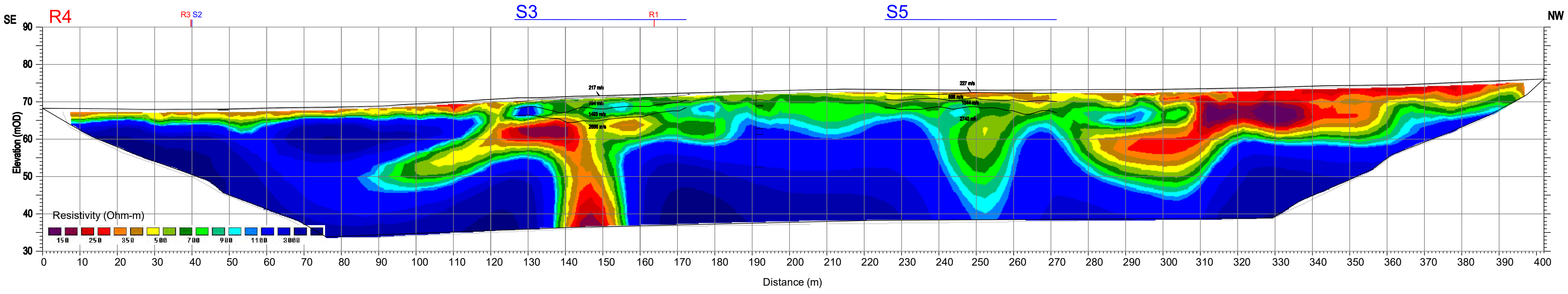
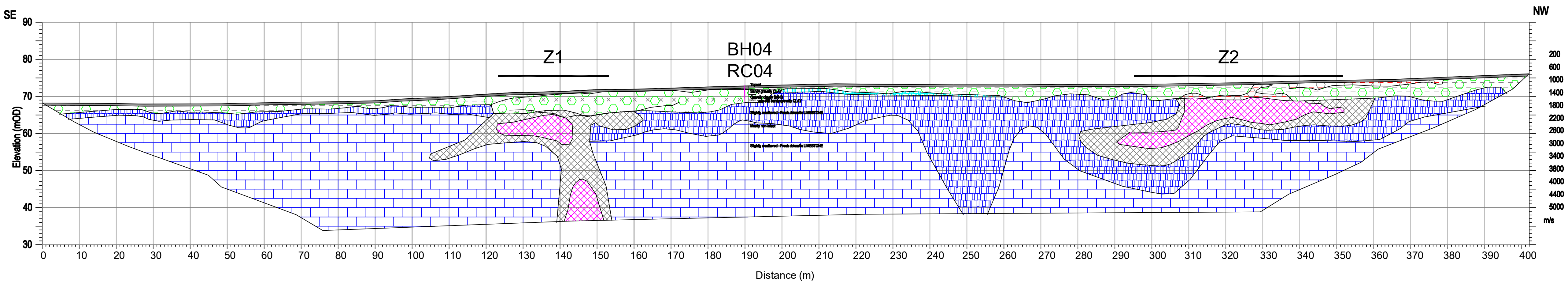



FIG.2.INTERPRETATION ERT R4 AND SEISMIC REFRACTION S3 & S5

SCALE 1:1250





**LEGEND:** interpreted P-wave velocity

- 1254-1288 m/s — Seismic refraction layer with interpreted P-wave velocity
- Soft/Loose TOPSOIL
- Stiff-very stiff Sandy Gravelly CLAY (possible weathered rock towards base)
- Medium Dense-Dense Clayey Sandy GRAVEL (possible weathered rock towards base)
- Medium Dense-Dense Silty Sandy GRAVEL/BOULDERS (possible weathered rock towards base)
- Rock with high degree of Karstification with clay infill
- Rock with some degree of karstification/fracturing/fissuring
- Highly - moderately weathered Dolomitic LIMESTONE/LIMESTONE
- Highly - moderately weathered Dolomitic LIMESTONE /LIMESTONE some cavities and clay infill
- Moderately - Slightly Weathered Dolomitic LIMESTONE /LIMESTONE
- Slightly weathered - fresh Dolomitic LIMESTONE /LIMESTONE

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CLIENT.: ENERGIA

DRAWING NO: AGP23061_R4

SCALE: AS INDICATED @ A3

DATE: 09-11-2023

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| 02 | 09-11-2023 | SC | TL |
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