NI GeoEnergy Demonstrator
787-B043623

Greenmount Geothermal Feasibility

Client Review

Department for the Economy

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TETRA TECH

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Acronyms/Abbreviations

Acronyms/Abbreviations	Definition
ANBC	Antrim and Newtownabbey Borough Council
CAFRE	College of Agriculture, Food and Rural Enterprise
CXA	A coaxial DBHE arrangement whereby fluid enters the annulus of borehole, flows to the base of the borehole, and returns up the borehole by the central coaxial pipe.
CXC	A coaxial DBHE arrangement whereby fluid enters the central pipe, flows to the base of the borehole, and returns up the borehole-by-borehole annulus.
DfE	Department for the Economy
DST	Drill Stem Test
ES	Environmental Statement
EWT	Extended Well test
PAD	Pre Application Discussion

Executive Summary

The GeoEnergy NI Demonstrator Project is a Northern Ireland Government initiative, funded by the Department for the Economy (DfE) to showcase and demystify geothermal energy. Geothermal energy is a low carbon, natural, and renewable energy source from beneath the Earth's surface and is already widely used successfully across the world. The GeoEnergy NI Demonstrator Project aims to familiarise the public with the subsurface, help build the geothermal energy sector, promote geothermal as a source of heating and cooling, gain public support and social acceptance for geothermal energy, de-risk future investment and support market sector development.

Northern Ireland has favourable geology for the development of low enthalpy (low temperature) geothermal energy projects. While there are no hot springs at surface, no natural geysers, there are aquifers (porous and permeable rock units) at depth that contain warm water due to the natural geothermal gradient. The Greenmount component of the study is aimed primarily at assessing the potential for the use of a deep geothermal energy source by drilling and testing of a geothermal doublet (2 wells) to depths of 1.5 to 2km. Land around the CAFRE (College of Agriculture, Food and Rural Enterprise) educational campus at Greenmount, Antrim, Northern Ireland has been identified as being located in an area underlain by a potentially significant deep geothermal resource, based upon earlier geological analysis and assessment.

The principal aquifers of interest to this study are found within the Permo-Triassic Sherwood Sandstone Group and the underlying Enler and Belfast Groups and this report describes a series of studies that have been completed to characterise the subsurface resource and prepare for future drilling and testing operations.

- A multiphysics ground based survey was carried out in 2023 (SLB 2025) to describe the location and depth of the target aquifers
- Two reports were completed on the geothermal resource within these aquifers (SI, 2024.and Causeway Energies 2024)
- A report was compiled on preliminary well designs and costings (Tetra Tech 2024a) and
- The Environmental Statement (ES) has been completed and required planning processes are underway (Tetra Tech, 2025) to enable future drilling and testing.

The work has confirmed the initial evaluation of a potential geothermal resource. Drilling wells this deep is expensive (perhaps costing £5-10M) and technically challenging but could potentially produce sufficient energy to heat a large public building or network of smaller commercial and residential options and as such represents a good opportunity to test the effectiveness of geothermal energy in Northern Ireland.

1.0 Introduction

1.1 Purpose

The GeoEnergy NI Demonstrator Project is a Northern Ireland Government initiative, funded by the Department for the Economy (DfE) to showcase and demystify geothermal energy. It aims to familiarise the public with the subsurface, help build the geothermal energy sector, promote geothermal as a source of heating and cooling, gain public support and social acceptance for geothermal energy, de-risk future investment and support market sector development.

1.2 Scope and Objectives

A key element of the Demonstrator project is the evaluation of the deep geothermal potential of the Permo-Triassic rocks underlying the CAFRE Greenmount campus to the east of Lough Neagh in Co. Antrim. The principal component of this evaluation will be the drilling and testing of two deep geothermal boreholes.

The interpretation of geophysical survey data, collected in 2023 and reported by SLB in 2025, has provided definition of the drill site geology and target aquifer depths. The effectiveness of the potential geothermal resource has been established in 2024, through studies completed by Causeway Energies and Sustainable Ideas.

The two boreholes will form a geothermal ‘doublet’. Warm water will be abstracted from one and reinjected to the aquifer via the second borehole.

Once drilled, the boreholes will be subject to both drill-stem tests and extended well tests (EWT) and if well testing is successful and proves the presence of a viable geothermal resource, permanent well heads will be installed for the development of a future geothermal energy scheme.

The purpose of this report is to summarise the results of the key work programmes completed to date and based upon these to establish the feasibility of a deep geothermal scheme at the site.

1.3 Methodology

The principal components of this evaluation have been:

- Building a robust subsurface model to describe the depth and location of the principal aquifer targets (the Permo-Triassic Sherwood Sandstone Group and Enler Group sandstones). New geophysical data were acquired, (seismic, gravity and magnetotelluric) and these data were interpreted and integrated with historical geophysical survey data for the area, geological mapping and historical deep boreholes drilled in proximity to the site, to develop an updated geological model. This is all documented in the Multiphysics study for Geothermal Demonstrator Project (SLB, 2025).

- Modelling the likely thermal outputs from those Permo-Triassic aquifers (SI, 2024. and Causeway Energy, 2024). The results from the two studies using 3 separate software packages, are in good agreement and indicate that a well drilled to Sherwood Sandstone level at the proposed site should encounter water with a temperature of approximately 45^{o}C and would have the capacity to produce between 1.5 to 2.0 MWth of thermal power.
- Generation of a preliminary well design to inform the business case for the project by defining the likely range of costs for the boreholes and any preparatory works (Preliminary Well design and Costings for Greenmount Deep Boreholes, Tetra Tech 2024).
- Environmental assessment and planning to assess and address the environmental impact of potential future operations and to seek permits for drilling and testing operations to commence in the future.

1.4 Site Location / description

The outline of the CAFRE campus and the location chosen for the drilling site is shown on Figure 1. This shows the red line boundary and illustrates access to the site from Oldstone Road in the west. The proposed development site has an approximate area of 11.45 hectares (ha), the extent of which is identified in the red line plan provided on Figure 1. The Site boundary is centred on Ordnance Survey (OS) Irish National Grid Reference J17050 84930 (Easting 317050, Northing 384930) and its approximate postcode is BT41 4QE.

The site is an irregular area located along the A26 Oldstone Road and is currently agricultural land (grassland fields). The agricultural land is classified under the Land Cover Map 2023 for Northern Ireland largely as ‘Improved Grassland’, with a small portion of ‘Neutral Grassland’ in the southern boundary of the site.

The main entrance to the site is located at its southwestern corner and is accessible via an internal vehicular track (part of the redline boundary) off A26 Oldstone Road, which runs along the western boundary of the site. The site also contains an unnamed road located to the north west/centre that leads to farm buildings and connects to A26 Oldstone Road. Numerous trees line the vehicular access track and extend into the southwestern corner of the site. Additionally, several trees and hedgerows are also found to the northeast of the site.

The site slopes 3-4^{o} from 62m to 40m towards Six Mile Water, the nearest watercourse, located c.200m from the northern boundary. The Six Mile Water drains to the largest freshwater body in Northern Ireland known as Lough Neagh, west of the site.

1.5 Low Enthalpy Geothermal Principles

There are two principal types of low enthalpy geothermal systems typically used in conjunction with Ground Source Heat Pumps (GSHP):

• Open-loop, where water is taken from the environment (aquifer, lake, river or estuary), passed through a heat exchanger, and is then returned to the environment. For this solution at Greenmount, groundwater would be abstracted from one borehole drilled into the aquifer beneath the site and then returned to that same aquifer via another recharge borehole.

• Closed-loop, where a carrier fluid is passed through sealed pipework or heat exchanger within the ground, collecting heat from the ground (or releasing it in cooling mode) in the process. This is not a proposed option at Greenmount. Heat exchangers are installed in boreholes drilled into the underlying bedrock, with the boreholes sealed up with grout and the associated pipework connected to sub-surface collector pipework systems.

2.0 Subsurface Characterisation

2.1 Geological Setting

2.1.1 Superficial Geology

The CAFRE site at Greenmount is covered with a mixed veneer of fluvio glacial deposits. The proposed drill site for the deep boreholes is located in the east of the overall site and is underlain by glacial till. The GSNI interpretation (Figure 2) has been confirmed by the Tetra Tech site investigation (2025) around the proposed borehole locations. Clay-rich superficial deposits are present across the southern and central area (mapped as glacial till) with a shallow depth to bedrock proven. Inferred weathered basalt bedrock/bedrock was encountered at 1-2m depth. In the north of the Proposed Development area, trial pits indicated more variable deposits with sandy clay, gravelly sand and sand and gravel encountered (mapped as Glaciofluvial Ice Contact Deposits).

2.1.2 Bedrock Geology

Figure 3 shows the bedrock geology at the CAFRE Greenmount site and illustrates that the basalts of the Antrim Lava Group lie directly beneath the superficial glacial cover. The geothermal target lies deeper in the geological sequence, in the Permo-Triassic Sherwood Sandstone Group.

Figure 4 illustrates the distribution, depth and expected temperatures of the Sherwood Sandstone Group in Northern Ireland. It lies at shallow depths beneath glacial deposits in Belfast and along the Lagan Valley but deepens to the north and west, where water temperatures of up to 100°C might be encountered (Raine and Reay, 2021). In areas where aquifers occur at shallower depth, such as in the Lagan Valley, the Sherwood Sandstone Group has for many years supported the abstraction of large volumes of groundwater for public and industrial water supply. This aquifer extends over a wide area and is present at variable depths throughout the UK and Europe. It is, for example, also employed as a geothermal aquifer for large-scale horticulture in the Netherlands (Raine and Reay, 2021).

A key component of project work completed so far has been to de-risk potential future deep drilling by characterising the nature and distribution of these Triassic and Permian aquifers where they are at greater depth in the Antrim area. A series of geophysical surveys was undertaken in 2023 with the results documented in the report 'Multiphysics study for Geothermal Demonstrator Project' (SLB 2025)

Figure 5 shows depth maps (SLB 2025) of the target geothermal aquifers beneath the CAFRE Greenmount site and illustrates that the Sherwood Sandstone Group is predicted to lie at a depth of -850m (AOD) and that the Enler Group at -1550m (AOD). Figure 6 is a 3-Dimensional image of the target horizons and illustrates that the drill site lies on a structural high between two major faults, the Browndod Fault to the NW and the Sixmilewater Fault to the SE.

2.2 Hydrogeological Setting

2.2.1 Aquifers

The hydrogeological setting of the site is described in detail in the Soils, Geology, Hydrology & Hydrogeology Report (Tetra Tech, 2025).

The targeted deep Permo-Triassic aquifers are saline and are not considered to have any resource value with respect to use for freshwater supply, they are not hydraulically connected to the surface water system and the geothermal doublet will be self-contained, warm water abstracted at depth will be returned to the same aquifer at lower temperature and always kept in isolation from shallower groundwater.

Understanding of the aquifers nearer the surface is however also critical to enable the design of safe wells and make sure the deep and shallow aquifers remain isolated and that no communication routes are created between them.

The majority of the proposed development site is underlain by lacustrine and glacial till deposits which have no significant aquifer potential and would be expected to have moderate to low permeability and contain limited groundwater. Sands and gravels of glaciofluvial ice deposits and alluvium deposits have primary porosity and would have the capacity to store and transmit groundwater. Groundwater flow direction in the glaciofluvial ice contact deposits and alluvium deposits is considered to be strongly controlled by the topography and drainage pattern.

The basalt bedrock below the superficial deposits is a recognised aquifer containing groundwater and with potential hydraulic connection to surface waters where bedrock is at/near surface.

The conceptual model for the Basalt/Ulster White Limestone/Hibernian Greensand aquifer system indicates that locally the anisotropic nature of the rock means that flow paths are likely to be generally short and influenced by local topography[1].

Based on the above, groundwater flow in the glacio-fluvial deposits and the upper bedrock below the proposed borehole site would be expected to be towards the Six Mile Water Valley to the north and to the north-west. There are no large water abstractions in the area which would locally influence groundwater flow.

[1] GSNI 2023 Northern Ireland's Groundwater Environment (Wilson et al)

2.2.2 Water Chemistry

The generalised hydrochemical properties of the main underlying aquifers are summarised in Table 1. This is based on data from across Northern Ireland where the bedrock aquifers are within a few hundred metres from surface. At depth, the water chemistry can be significantly different and is typically more mineralised. NaCl concentration in brines abstracted at Ballymacilroy was 120g/l, four times that of seawater. High mineral content can cause issues with scaling of boreholes, pipes and heat exchangers and to minimise these risks it is important that abstracted water is not allowed to come in to contact with atmospheric oxygen, that degassing of any CO_2 is minimised and that pressures are managed through the whole process from water abstraction through the heat exchanger and back to the injector well.

Table 1: Aquifer General Hydrochemical Properties

Geology	Aquifer Chemistry
Lower Basalt Formation (Palaeogene)	Groundwater typically moderately mineralised (median conductivity 443 µS/cm). Groundwater typically of calcium or sodium bicarbonate type away from coastal areas.
Ulster White Limestone Formation/Hibernian Greensands Formations (Cretaceous)	Groundwater typically relatively weakly mineralised (median conductivity 349µS/cm) with slightly alkaline pH. Groundwater typically of calcium bicarbonate type.
Sherwood Sandstone Group (Triassic)	Groundwater (where aquifer near surface) typically relatively more mineralised (median conductivity 513 µS/cm) and with higher pH (median 7.68) than most other shallow groundwaters in Northern Ireland. Groundwater typically of bicarbonate type, with no dominant cation. At the depth the Sherwood Sandstone will be at in the drilled geothermal boreholes, groundwater will be significantly more mineralised/saline.
Enler Group (Permian)	Groundwater (where aquifer near surface) typically relatively more mineralised (median conductivity 513 µS/cm) and with higher pH (median 7.68) than most other shallow groundwaters in Northern Ireland. Groundwater typically of bicarbonate type, with no dominant cation. At the depth the Permian Sandstone will be at in the drilled geothermal boreholes, groundwater will be significantly more mineralised/saline.

3.0 Drilling and Borehole Design

3.1.1 Borehole Design (technical objectives, constraints and solutions)

As described, the technical objective is to drill and test the geothermal potential of the Triassic age Sherwood Sandstone Group (and potentially the Permian age Enler Group Sandstones) beneath the campus at CAFRE.

The Preliminary Well Design and Costings report (Tetra Tech 2024a) describes the key features of the required borehole designs. The two boreholes will form a geothermal 'doublet' where warm water is be abstracted from one and reinjected to the aquifer via the second borehole.

The boreholes will be drilled from a single well pad located in the east of the overall development site (Figure 1) and deviated away from each other, to achieve a separation of more than 500m at top of the primary aquifer. This separation is required to minimise the risk of thermal feedback, where cooled water reinjected to the aquifer works its way back to the abstraction well, reducing the temperature of the produced water and reducing the efficiency of the system.

As described above, the two well bores are deviated at 180° to each other to achieve maximum separation at the top of the aquifer. The absolute orientation has been chosen to maximise water flow. Flow from the Sherwood aquifer is usually dominated by flow through natural fractures in the rock (rather than through inter-granular flow). A greater number of fractures is expected if the well bore is orientated perpendicular to the assumed minimum compressive stress. This is, in turn, assumed to be parallel to the orientation of Tertiary dyke intrusion (orientated approximately ENE-WSW, Anderson et al, 2014, Anderson et al 2018). This is consistent with the minimum compressive stress orientation identified by the BGS for the rest of the UK. The deviation of the well bores (departure from vertical) is constrained by the CAFRE ownership boundary as the drilled well bores must remain within the site. As a consequence, a larger proportion of the required 500m separation is provided by Borehole #2 which has a longer step-out (higher deviation) to the SW. There is no site boundary constraint to the SW but SLB (2025) do map a fault close to the currently planned target depth (TD) and this may need consideration when planning the final well bore trajectories as borehole stability may be an issue if associated fracturing is significant.

The wells will be subject to both Drill Stem Testing (DST) and Extended Well Testing (EWT). The preliminary design is shown in Figure (7).

4.0 Environmental Assessment & Site Selection

4.1.1 Introduction

Tetra Tech has undertaken a programme of work to assess the environmental impact of the proposed drilling activities at the site and this is documented in the Environmental Statement (ES) (Tetra Tech, 2025). The ES was produced in accordance with The Planning (Environmental Impact Assessment) (Northern Ireland) Regulations 2017 and accompanies a suite of agreed documents that together form a single planning application being submitted to Antrim and Newtownabbey Borough Council (ANBC) for the drilling and testing of the two deep geothermal boreholes.

A desktop review of potential environmental constraints was undertaken using publicly accessible online sources as well as the findings of individual technical assessments, that in some cases have included site visits, surveys and investigations. A summary of the key receptors is included in the ES. The final borehole location was selected to minimise any impacts on these receptors and the ES now documents the proposed site, all potentially impacted receptors and the detailed plans being proposed to mitigate the potential impacts.

The planning process is underway with the initial planning meeting held with ANBC on 10 January 2025.

Key Milestones in the planning process are:

- Proposal of Application Notice (PAN), reference LA03/2024/0776/PAN provides a description of the proposed development, a site location plan, and a summary of the consultation activities undertaken as part of the project. The PAN was submitted to Antrim and Newtownabbey Borough Council (ANBC) on 25 October 2024.
- ANBC responded to confirm receipt of the PAN on 30 October 2024.
- On 14 November 2024, the Council as the planning authority confirmed that it found the PAN contained sufficient information with regards to community consultation measures and therefore considered it complies with Section 27 provisions of the 2011 Planning Act.
- Pre-Application Community Consultation(PACC) public consultation event at the Antrim Forum, on Friday 22nd November between 12-2pm and 4-7pm
- Pre-Application Discussion (PAD) meeting with ANBC 10th January 2025

5.0 Geothermal Resource Assessment

5.1 Greenmount Geothermal Potential

5.1.1 Introduction

While the shallow geothermal potential of the Permo-Triassic sequence has been tested at Stormont during 2024, the work at Greenmount focused on investigating the geothermal potential of these same rocks where they occur at depths of up to 1.5-2.0km and where higher water temperatures are expected. Saline water at a temperature of 62°C was recovered from Permian Sandstones at a depth of 1.5km at Ballymacilroy, (17km to the northwest of the Greenmount site). The water temperature at Greenmount itself is expected to be around 45°C at a depth of 850m (Causeway Energies, 2024, SI Ltd, 2024).

5.1.2 Summary of SI Open Loop Report

Sustainable Ideas (SI) was commissioned to undertake modelling to estimate the potential quantities of heat that can be sustainably extracted from mid-deep to deep geothermal systems.

SI modelled a notional deep coaxial borehole heat exchanger (DBHE) with a constant heat load over a 25-year period to estimate the thermal yield at 1km and 2km, under lithological variations, varying flow direction, various circulation flow rate and with subsurface groundwater flow applied. Also, a notional geothermal (open-loop) doublet was modelled for varying depths of 1 and 2 km to produce probability estimates of pre-drill indicative heat power and an estimate of the anticipated time to thermal breakthrough at a range of separation distances between the wells.

OpenGeoSys and DoubletCalc software was used for closed- and open-loop scenarios, respectively. The conclusions from the modelling results for these notional geothermal systems can be summarised as follows:

- 1 km open-loop (Sherwood Sandstone): A "best estimate" thermal power of 2.2MWth can be achieved over 25 years without thermal breakthrough with a circulation flow rate of 24.4kg/s from a doublet spaced at 1 km. The resulting pressure "drawdown" in the production well is 16 bar. The production temperature is 46.4°C. This result assumes an average permeability in the upper part of the Sherwood Sandstone of 72mD, a reservoir thickness of 230m, a transmissivity of 16.6 Dm and a reinjection temperature of 25°C.
- 2 km open-loop (Upper Permian Sandstone reservoir): A "best estimate" thermal power of 1.96MWth could be achieved from the reservoir based on the deterministic simulations, with a pressure "drawdown" in the production well of 13.2 bar (although it is estimated as 1.5 MWth when accounting for other losses in the system for the P50 1D scenario). In contrast

to the 1 km scenario, the circulation flow rate would be lower (8.5kg/s), but there would be a greater outlet temperature of 80.7 °C. This result assumes an average permeability in the Upper Permian Sandstone of 72mD, a reservoir thickness of 65 m, a transmissivity of 4.7 Dm and a reinjection temperature of 25°C. Thermal breakthrough does not occur during the base case (1 km doublet separation) scenario and is very modest at a well spacing of 500 m. Thermal breakthrough within 25 years is observed for a doublet spacing of 250m, or at higher circulation flow rates.

- 1 km closed-loop: A thermal power of approx. 4 kWth can be achieved with a flow rate of 5 kg/s, without the inlet temperature falling below 5 °C. When convection via groundwater flow is considered (with a Darcy velocity of 1e-6 m/s), this increases to 67kWth. Also, with a circulation fluid flow rate of 10kg/s (rather than 5 kg/s), a marginal increase to 51kWth is possible. However, this additional thermal power needs to be considered along with increase in parasitic losses. The CXA[2] flow configuration has a slightly higher outlet temperature of 0.9 °C more than the CXC[3] flow configuration.

2 km closed-loop: A thermal power of 157 kWth was obtained with a flow rate of 5 kg/s, without the inlet temperature falling below 5 °C. This results in a lifetime (25 year) thermal production of 36,850 MWhth. The direction of flow had a minor impact on performance, with the CXA flow direction being more beneficial by 9.3kW. Increasing the mass flow rate led to greater thermal output. In contrast to the 1 km scenario, the application of groundwater flow to the model across the Antrim Lava Group, Ulster White Limestone Formation, and the Sherwood Sandstone Group resulted in an increase in thermal power to 232kWth. This is due to the replenishment of warmth by groundwater flow in the cooled zone around the DBHE. These results are highly contingent on:

- for closed-loop, the minimum acceptable fluid temperature to the DBHE (5°C was assumed);
- for open-loop, the minimum acceptable reinjection temperature (25°C was assumed), and the maximum acceptable pressure changes in the abstraction and reinjection wells.

Significantly higher return temperatures will result in a reduction in thermal output from the system. It was also noted that there is significant variation in the burial depth of the key Permo Triassic aquifers and that this would impact the parameters and therefore also impact the potential thermal output.

[2] a coaxial DBHE arrangement whereby fluid enters the annulus of borehole, flows to the base of the borehole, and returns up the borehole by the central coaxial pipe

[3] a coaxial DBHE arrangement whereby fluid enters the central pipe, flows to the base of the borehole, and returns up the borehole by borehole annulus

5.1.3 Summary of Causeway Energies Report

Causeway Energies also completed a review of the heat potential at the site in 2024 (Causeway Energies, 2024) and modelled the thermal output of aquifers at 1.0km and 2.0km. The numerical models were built in FEFLOW and confirm the requirement for at least 200m separation of the abstraction and injection wells. For the 1.0km scenario where the aquifer is at a temperature of about 40ºC, preliminary analysis suggests that a flow rate of 20L/s, with a 20ºC delta T is a reasonable conservative minimum case forecast for a doublet. The thermal power of this case is ~1.7 MW. This equivalent to 335GWh of thermal energy over 25 years, assuming a 90% utilization. The most likely case was 30L/s with the same delta T but this scenario demonstrates a modest decline in thermal output by about 16 years. The thermal power for this case is ~2.5MW, equivalent to 493GWh of thermal energy over project life.

For the 2.0km scenario, while the aquifer is deeper and therefore hotter (around 80ºC), the permeability is lower and the most likely case is 20L/s with a thermal power output of ~1.65 MW. This is equivalent to 325GWh of thermal energy over 25 years, again assuming a 90% utilization.

For a closed loop deep borehole heat exchanger (DBHE) Causeway Energies predicted long term (mid project life) thermal powers of 75 to 85kW.

The Causeway Energies report (2024) also includes an analysis of economics, the results of which illustrate that Deep Geothermal Heat Pumps using productive hydrothermal aquifers like the Sherwood Sandstone have very high potential to deliver very cost competitive, low/zero carbon heat in Northern Ireland.

5.1.4 Comparison of Results

Despite differences in detailed assumptions, parameters and even units used in reporting[4], the results are in good agreement and indicate that a well drilled to the level of the Sherwood Sandstone at the proposed site should encounter water with a temperature of approximately 45ºC (see Table 1). At the deeper Enler Group level, the depths indicated by the SLB Multiphysics work would indicate the aquifer at approximately 1,500m depth so temperatures will be lower than those shown in Table 1, as the aquifer is less deep.

Table 2 Modelled groundwater temperature at target aquifer depth

	Sherwood Sandstone Group	Enler Group
Causeway Energies		

[4] For example a flow rate of 1kg/sec is almost identical to 1l/sec as a litre of pure water has a mass of 1kg at 4ºC

	Sherwood Sandstone Group	Enler Group
Top depth (m)	750	2327
Production temperature	45^{o} C	85^{o} C
SI (Glasgow University)		
Top depth (m)	900	1960
Production temperature[5]	46.4	80.7
Ballymacilroy 62^{o}C @1.5km[6]		

Based on the modelled water production rates and at these temperatures, it is estimated that a borehole doublet at this location would have the capacity to produce between 1.5 to 2.0 MWth of thermal power.

[5] Stated geothermal gradient 35.5oC/km 10oC surface temperature

[6] Saline water at a temperature of 62^{o}C was recovered from Permian Sandstones at a depth of 1.5km at Ballymacilroy, 17km to the northwest of the Greenmount site

6.0 Heat Utilisation

The possible thermal energy yield from the proposed borehole doublet (1.5 to 2.0 MWth) has no currently planned use but this level of thermal power could heat a large public building (as an example, making a number of assumptions on annual heat distribution and usage, the Parliament Buildings at Stormont require an energy supply equivalent to about three quarters of this demand).

An alternative would be to build a heat network to distribute this energy to multiple new users (commercial or domestic or related to the CAFRE campus itself).

7.0 Costings

7.1.1 Introduction

At present, with no planned usage for the thermal energy that could be produced by the scheme, there are no capital costs associated with the implementation of a scheme, only estimates of costs likely to be incurred in the preparation for and completion of the drilling and testing operations at the site. These are documented below.

7.1.2 Borehole Costing

The principal reason for generating a provisional design for the proposed boreholes was to enable an estimate of potential cost for future project budgeting. The analysis suggested that the total cost to complete the site preparations and both drill and complete the two geothermal boreholes is likely to range from £6.20-£9.96mm. Key points to note include:

- These costs are Tetra Tech estimates of the costs that might be incurred drilling the wells if contracted immediately, drilled as planned and with no issues.
- With no firm timetable for operations, it should be noted that if the project is delayed, the rates and costs presented in this report could change and will need to be revisited.
- At this early stage, the project scope may be changed as objectives and the associated costs are reworked and specific elements removed or added. For example, the current scope includes tagging the top of the secondary Permian aquifer in both wells but testing it in neither. There is currently no plan to core in either well.
- The main cost uncertainties are driven by the rig spread rate (the cost of the rig and all ancillary services) which will be difficult to resolve without a formal tender process.
- The estimated drilling duration is based on operations on similar wells in Northern Ireland but includes no further allowance for unexpected sub-surface conditions.
- With a limited rig supply, lead time on rig delivery is difficult to predict.
- Another major uncertainty in the costs is associated with the rig mobilisation. The range in rates is due to the relative scarcity of rigs and the distances to the locations of rigs from Europe. All the rigs outside the UK are between 1500 and 3000km distant.

Tetra Tech also investigated published costs of delivering similar schemes in Europe although this data is generally confidential and rarely available, Ungemach et al, 2019 describe the drilling of a geothermal doublet in Cachan, Paris. They document a budget of €14-15M but this is from 2017 and for more complex wells with extensive horizontal sections.

7.1.3 CO2 Abatement

There is currently no CO_2 footprint at the proposed site as there is no existing development. The borehole doublet is planned for a greenfield site with no current energy consumption. It is, however, perhaps still informative to calculate the CO_2 saving if this level of thermal energy was being used to replace gas fuelled heating. On the simplistic basis that this nominal 'gas' is replaced entirely by heat derived from an open-loop GSHP and that the heat pump has a CoP of 3.5 then the CO_2 saving is estimated at 300-600 tonnes per annum. This equivalent to taking approximately 90-140 petrol cars off the road each year or 2700-4200 cars over the 30-year design life.

Table 3 Simplified CO2 Abatement

Greenmount potential energy production	CO_2 from consumed gas	electricity to drive equivalent heat pumps (CoP=3.5)	$CO_2$from electricity for heat pumps	CO_2 reduction	CO_2 reduction over 30 year project life
3300	602	943	220	383	11477
4840	883	1383	322	561	16833

8.0 Uncertainty & Risk

While this study supports initial preparatory work in confirming the geothermal potential of the rocks beneath the CAFRE site, there are still significant uncertainties in the operational details for drilling the wells and in the long-term performance of a geothermal system should the resource be proven present.

- Geological Risk – the presence and depth of the aquifer as well as the temperature are now better constrained but water flow will need to be maintained over longer term to guarantee performance of a geothermal doublet. This will be dependent upon the porosity/permeability and connectivity of the aquifer. Fracture flow is generally important within Permo-Triassic aquifers but the nature of potential fracturing in the aquifer at this site is presently unknown as is the possible impact of Tertiary dykes and intrusions which are known to impact groundwater flow in aquifers across Northern Ireland.
- Operational Risk Successful drilling of the well will require a contractor who can cost effectively drill to the aquifer and complete effective abstraction and injection wells. This will be a first of a kind (deep geothermal doublet in Northern Ireland). There are no rigs capable of drilling these wells currently on the island or Ireland and any drill crew will be inexperienced at drilling a well of this type in this location. The tight rig supply locally not only impacts potential costs (below) but also the timing of any drilling programme when rigs must mobilise from GB or Europe
- Cost Risk: current costings are estimates based on 2024 market intelligence. This could change significantly once the project goes out to tender and then may change further if the job escalates due to drilling problems.

9.0 Conclusion and Recommendations

The work detailed in this report confirms earlier evaluation that the Permo-Triassic sequence in this location is a suitable target for geothermal investigation. From a subsurface perspective, the scheme appears to be a feasible proposition. The (SLB, 2025) Multiphysics report produced as part of the GeoEnergy NI project reduces risk and uncertainty around the location and depth of the two principal aquifers and SI and Causeway Energies reports produce similar evaluations of the thermal resource within those rocks at depth. There are still technical uncertainties in all three studies that could be reduced by further work but the principal remaining uncertainties are now around securing planning consent for the operations and in the cost and timing uncertainties that surround securing a rig that can drill the wells and provide the ultimate test of this geothermal concept.

While the Causeway Energies report suggests deep geothermal projects should be economically attractive in Northern Ireland, with no identified use for the thermal heat that could be produced at this site, this specific scheme is not currently commercially attractive. This may not be the primary objective of the project, however identification of initial heat users would be beneficial not just to use heat that has been paid for up-front but also as it would allow the long-term testing of the geothermal facility.

10.0 References

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Figures

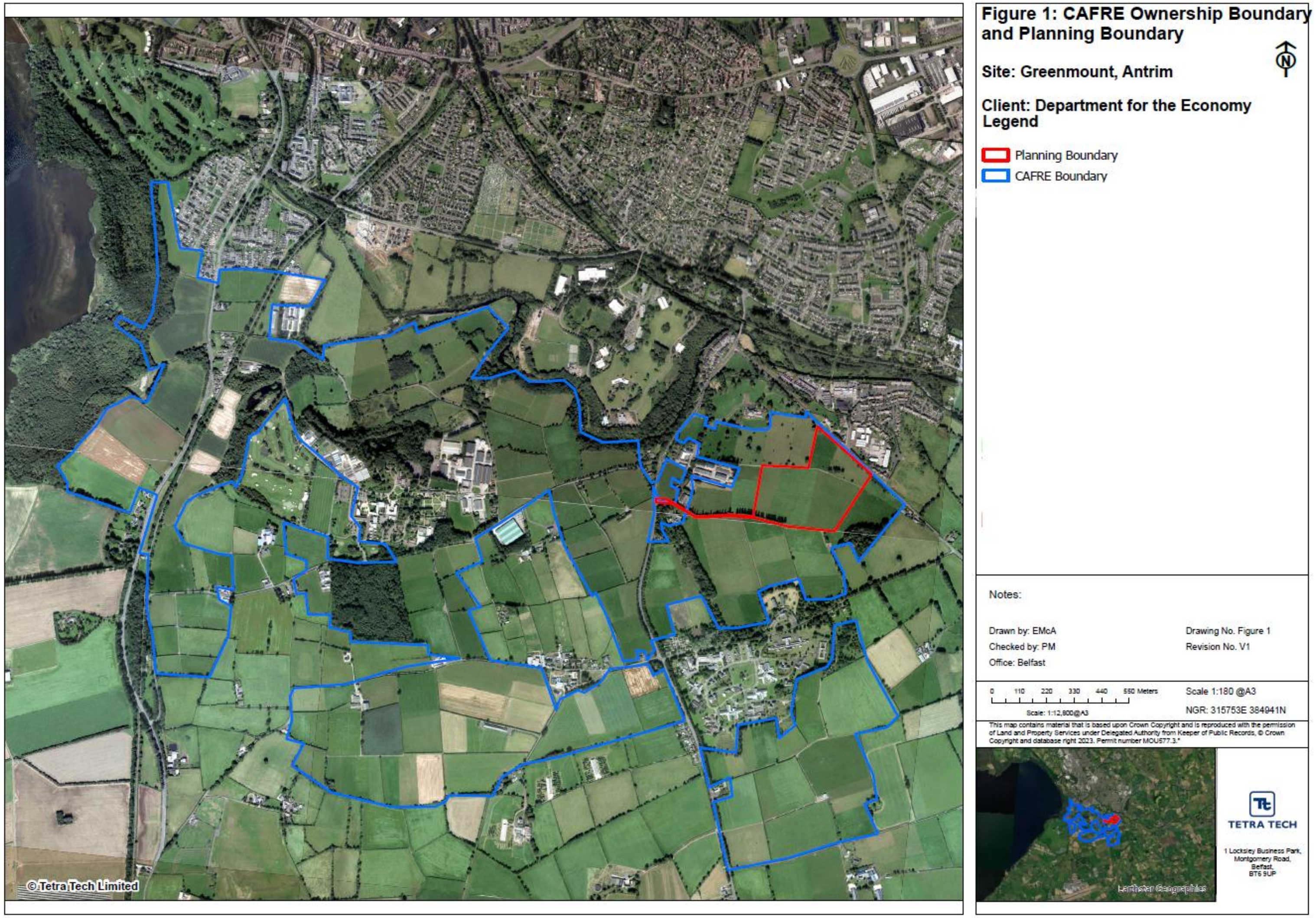

Figure 1: CAFRE Ownership Boundary & Planning Boundary

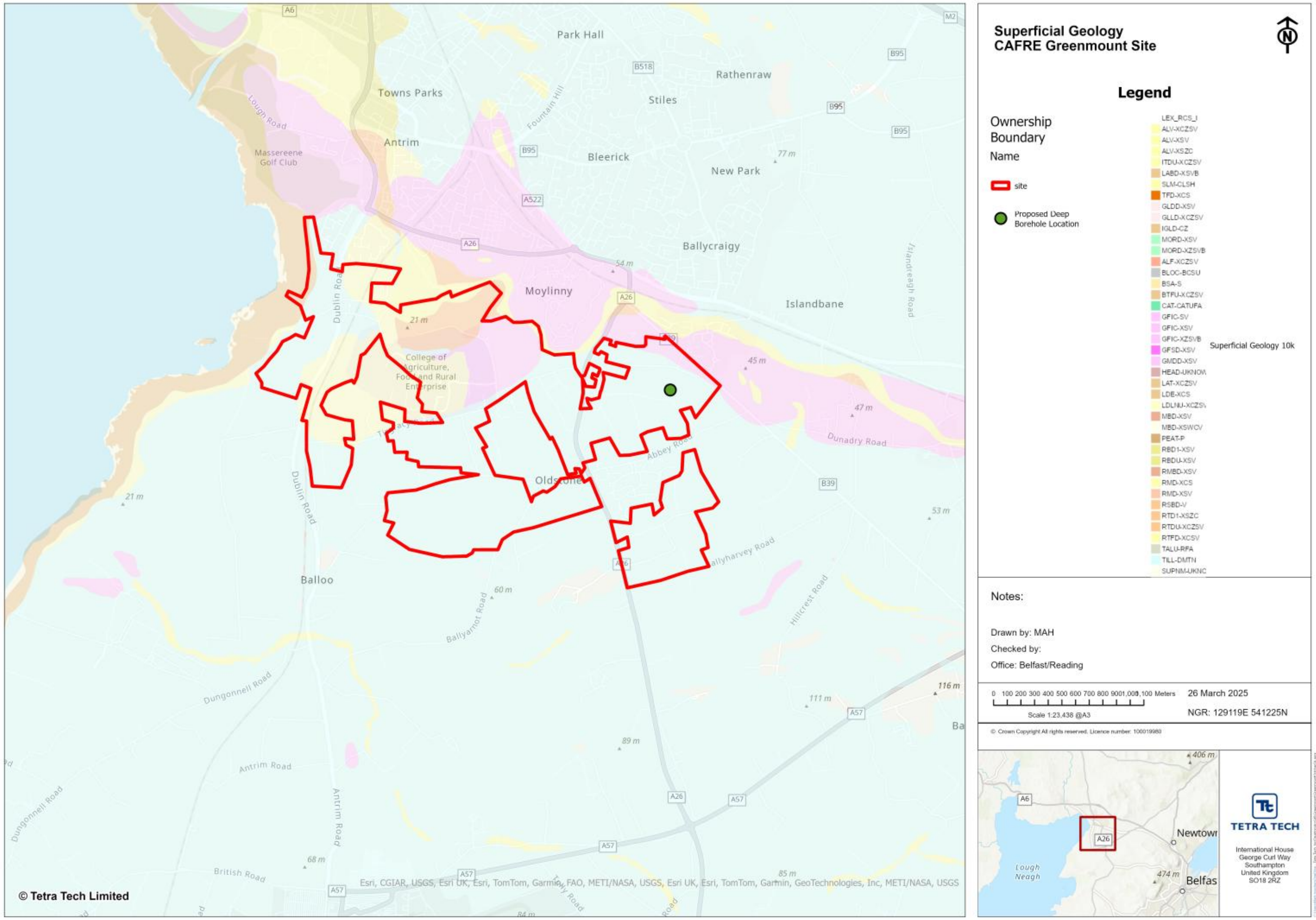

Figure 2: Superficial Geology at the CAFRE Greenmount site of the proposed deep boreholes

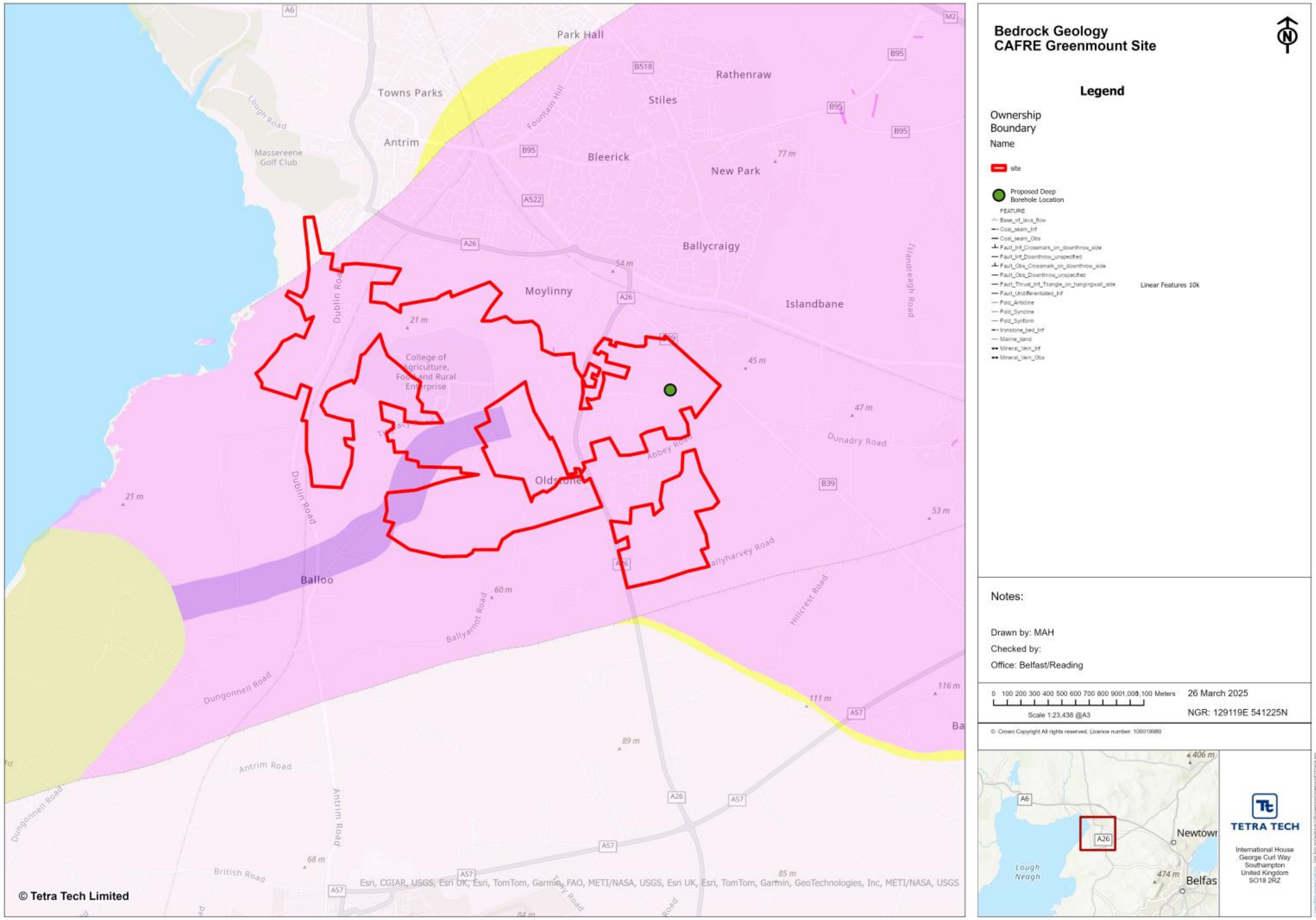

Figure 3: Bedrock Geology at the CAFRE Greenmount site of the proposed deep boreholes

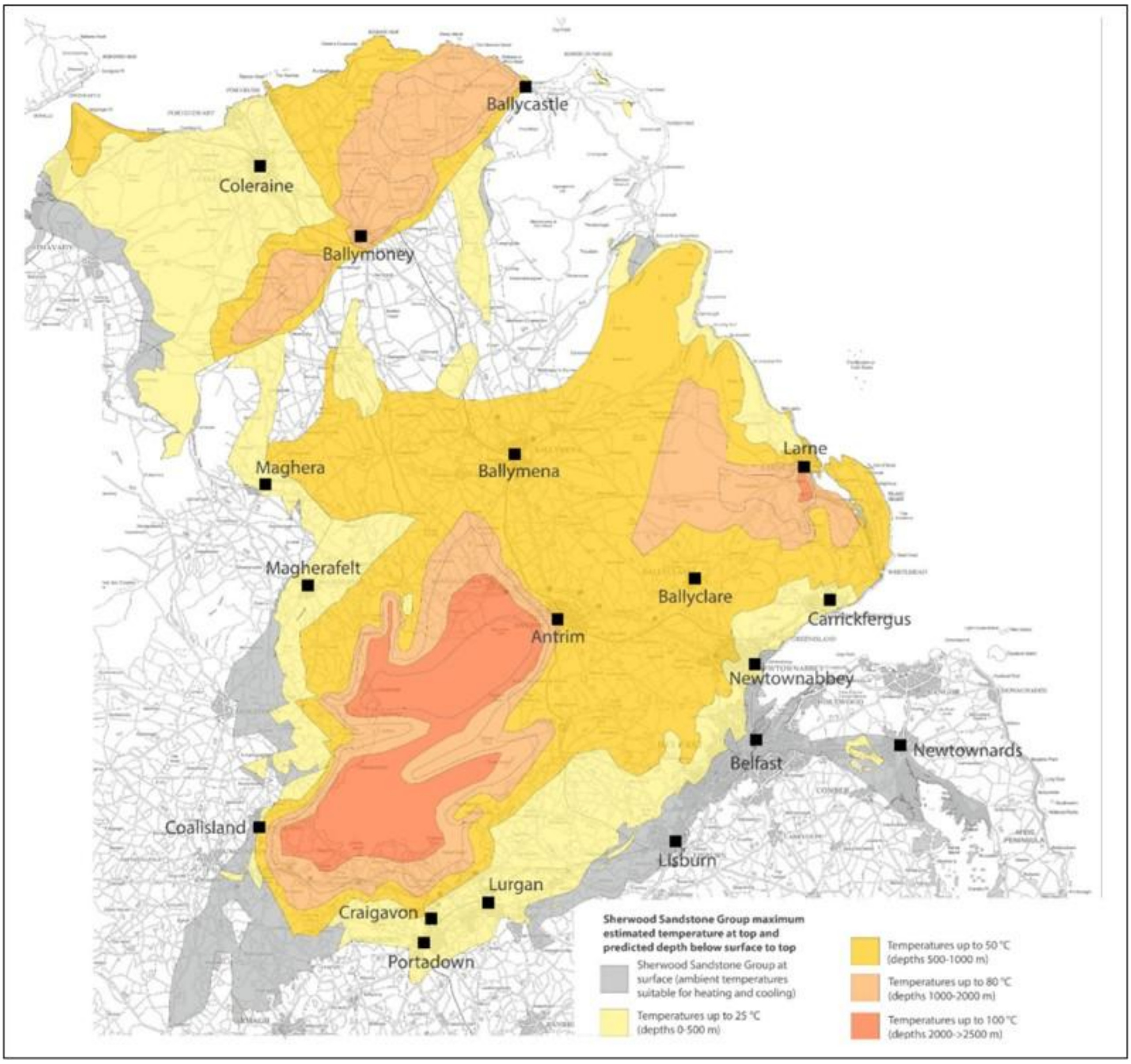

Figure 4 Predicted depth to top Sherwood Sandstone colour coded to show indicative temperature estimates based on the geothermal gradient (from Raine & Reay 2021)

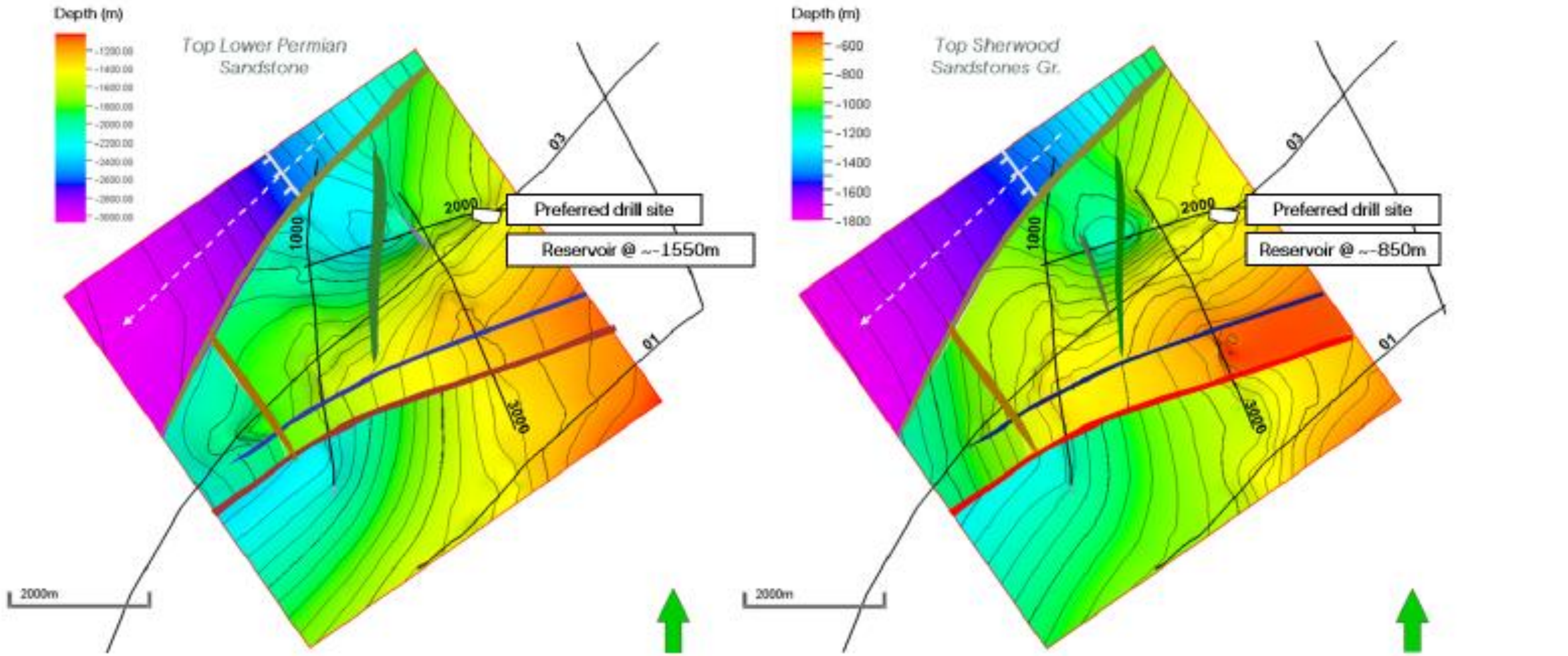

Figure 5: SLB (2025) Final structural maps for the top Enler and Sherwood Sandstone Groups

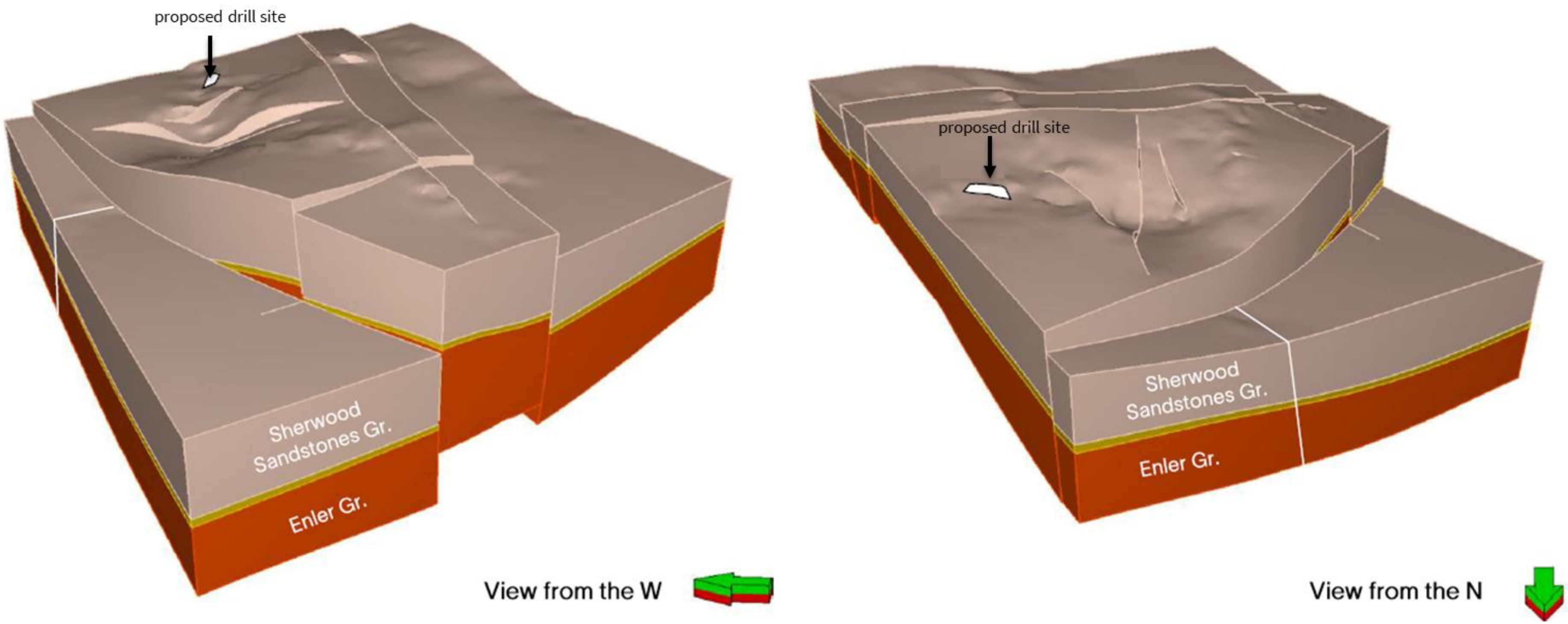

Figure 6: SLB (2025) Structural model illustrating that the proposed drill site lies on a structural high between two major faults

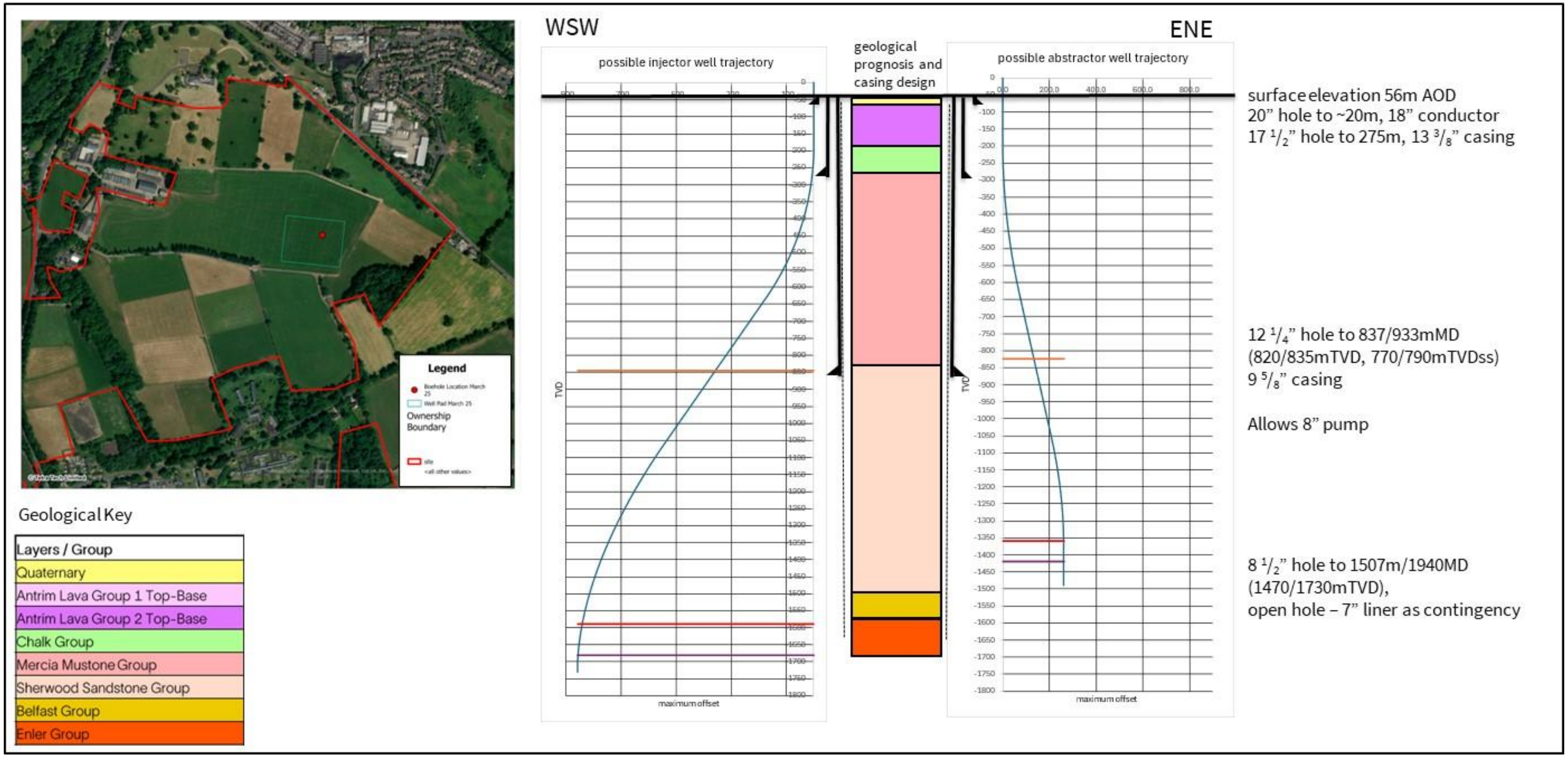

Figure 7: preliminary design for deep borehole doublet wells drilled from same pad (location map left) and deviated away from each other to maximise separation