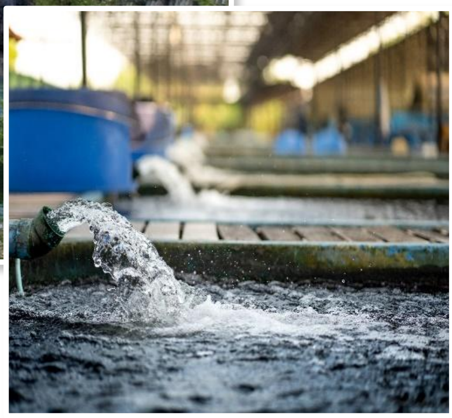
# GeoDemonstrator NI

787-B043623



**Preliminary Well Design and Costings for Greenmount Deep Boreholes**

**Department for the Economy**

**March 2025**

**Document prepared on behalf of Tetra Tech Consulting (Northern Ireland) Limited: No. NI667243**

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# Acronyms/Abbreviations

| Acronyms/Abbreviations | Definition |
|---|---|
| ALG | Antrim Lava Group |
| CAFRE | College of Agriculture, Food and Rural Enterprise |
| CE | Cost Element |
| DfE | Department for the Economy |
| DST | Drill Stem Test |
| EWT | Extended Well test |
| MD | Measured Depth (from surface along well track) |
| TVD ss | Total Vertical Depth (sub-sea) i.e. relative to Ordnance Datum |
| UWLF | Ulster White Limestone Formation (The Chalk) |

# 1.0 Introduction - The GeoEnergy Project

The DfE is proposing to drill and test two deep geothermal boreholes at the CAFRE Greenmount campus in Antrim. This study forms part of a larger geothermal demonstrator Project, a NI Government initiative funded by the Department for the Economy (DfE) to showcase and demystify geothermal energy. Its aims are to:

- Familiarise the public with the subsurface,
- 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.

The boreholes are to test the geothermal potential of the Triassic age Sherwood Sandstone Group (and potentially the Permian age Enler Group Sandstones) beneath the campus at CAFRE (College of Agriculture, Food and Rural Enterprise) to the east of Lough Neagh in Co. Antrim. The interpretation of geophysical survey data, collected in 2023, has provided definition of the drill site geology and target aquifer depths (SLB, 2025). The effectiveness of the potential geothermal resource has been established through other studies which form an integral part of the larger GeoEnergy NI Project (Causeway Energies, 2024, Sustainable Ideas, 2024).

The two boreholes will form a geothermal ‘doublet’. Warm water will be abstracted from one and reinjected to the aquifer via the second borehole. They will be drilled from a single well pad 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. The wells will be subject to both Drill Stem Testing (DST) and Extended Well Testing (EWT). 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 while the wider drill site will be restored to its former state. If the drilling and subsequent testing of the boreholes should fail to prove a viable geothermal resource, the boreholes will be plugged and abandoned and the entire site returned to its former state. The purpose of this report is to inform the business case for the project by defining the likely range of costs for the boreholes and any preparatory works. The preferred drilling site has now been identified and this report can now document the preliminary well plans and the high-level, cost estimates derived therefrom.

# 2.0 Site Preparation

## 2.1 Site Outline:

The outline of the CAFRE campus and the location chosen for the drilling site is shown on Figure 1. Figure 2 shows the red line boundary and illustrates access to the site from Oldstone Road in the west. Figure 3 and Figure 4 show the site topography and illustrates that the site slopes down to the north at 3-4$^{o}$ from a high of approximately 62m to 40m in the south.

## 2.2 Site Preparation Operations:

The drilling compound must be levelled to ensure a level working platform for the rig and an impermeable membrane installed to protect the underlying environment. Existing data shows that the site is underlain at shallow depth by basalts of the Antrim Lava Group (ALG). Site investigation work, earthworks specifications and slope stability assessment will be required to precisely define the nature of the cut and fill programme required to allow pad construction and make sure a level working platform for the rig and associated equipment. A sketch to illustrate the proposed site cross section is shown on Figure 4.

The topsoil will be removed and stored in an earth bund and in a soil storage area to the west of the rig enclosure (Figure 3).

An impermeable membrane will then need to be laid across the site and heat welded to provide integrity. The membrane is similar to those used for landfills and other engineering purposes and is typically made from High Density Polyethylene (HDPE). The membrane will cover the entire footprint of the planned drilling compound and will need to be protected above and below by a non-woven geotextile. A drainage ditch will need to be constructed around the perimeter of the site with surface water directed to the ditch prior to collection or off-site discharge under consent. The ditch will be lined with the membrane, to make sure water and other fluids are contained.

The site will be restored upon completion of the drilling operations.

# 3.0 Preliminary Well Design

Figure 5 illustrates the initial geological prognosis, well trajectories and casing plan.

## 3.1 Geological Prognosis:

The depths of all the key geological horizons have been derived from the multiphysics interpretation completed by SLB as a part of this project (SLB, 2025). A representative map showing the depth to the top of the principal Sherwood Sandstone aquifer is illustrated on Figure 6. It shows where the top aquifer is intercepted by the proposed well bores and demonstrates that the section dips toward the NW, with Borehole#1 encountering the aquifer some 15m shallower than Borehole #2. Borehole#1 is expected to be the abstraction well, Borehole#2, with the longer aquifer section is expected to be the injection well.

## 3.2 Well Trajectories

As described above, the two well bores are deviated at 180º to each other to achieve maximum separation at top 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 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 plan is to set an 18” surface conductor to a depth of 20m and drill both the boreholes vertically. A 17 ½” hole is proposed from the base of the conductor casing through the Antrim Lava Group (ALG) to just below the base of the Ulster White Limestone Group (UWLG) at approximately 190m where 13 3/8” casing will be set. The deviated sections of both boreholes will kick-off in the Mercia Mudstone Group (MMG). The build angle will be as high as 2.7$^{o}$ in Borehole #2, but only 1.2$^{o}$ in Borehole #1. It is proposed that the boreholes be drilled using a 12 ¼” bit to just below the top of the Sherwood Sandstone Group (SSG), at which point 9 5/8” casing is to be installed. Drilling is expected to resume with an 8 ½” hole being drilled and the build angle will be held through the uppermost aquifer as this is the most friable and potentially unstable aquifer section. The build angle will be allowed to drop back to vertical to reduce drill depth to the secondary aquifer (and to make sure Borehole#1 stays within the site boundary).

Borehole #1 is a simpler construction than Borehole #2 and is expected to encounter the target Sherwood Sandstone aquifer at shallower depth. Both boreholes are deviated away from vertical (and away from each other) and are orientated approximately ENE-WSW to optimise geological characteristics of the target Sherwood Sandstone aquifer. As well as being more deviated from vertical, the Sherwood Sandstone aquifer is also at slightly greater depth at the Borehole #2 location.

The planned well trajectory for Borehole #1 is closer to vertical as the potential step-out is constrained by the site boundary to the NE. It should be the first drilled to make sure that learnings from this initial simpler well can be applied to drilling the second well which is deviated further and has a longer more inclined drilled section.

## 3.3 Casing Design

The two principal considerations controlling the proposed casing design are the requirement to house the size of pump necessary to lift the potential warm water from the aquifer to the surface, and the need to isolate and protect the shallow surface aquifers in the ALG and UWLG (Chalk). It has been assumed that it will be necessary to use an 8-inch pump as this is driven by the water level encountered in the

Sherwood Sandstone (which was as deep as 113mbgl (-40mAOD) in Ballymacilroy, 17km to the NW) and the need to produce water at sufficient rates to create the required heating capacity. The pump should sit inside the casing just above aquifer level and this consequently sets the size of the casing at this level at 9 5/8". Shallower casings have to be sufficiently large to drill the subsequent hole sections which results in a 13 3/8" casing to isolate the Chalk and the basalt and an 18" conductor at surface.

# 4.0 Drilling Operations

## 4.1 Construction of Drilling Cellar

Two drill cellars will likely be constructed close to the centre of the drill pad, one for each borehole. They will be separated by a minimum of 5m along the centre line of the rig. These form containment areas from which each borehole can be drilled, they house the wellheads. They are constructed from pre-cast concrete rings with approximately 2700mm nominal diameter. The impermeable membrane is incorporated into the cellar construction to maintain the integrity of the site.

## 4.2 Installation of Surface Conductor

A water well rig may be mobilised to site ahead of the main drilling operations. This rig will drill the top-hole sections for both boreholes from surface, through the superficial deposits to a Total Depth (TD) of approximately 20m. Once the target depths have been reached, 18" diameter conductor (steel casing) will be installed to TD and cemented in place.

## 4.3 Drill rig mobilisation

Upon completion of site preparation and once the conductors are set, the main drilling rig and ancillary equipment will be mobilised to site. It should be noted that the drilling rig and contractor are not yet identified/selected and there may be some variation in detail and layout between individual rigs. The rig will be transported to site as multiple component loads in the sequence they are required; these will then be laid out and assembled. The process is expected to take a week to 10 days.

## 4.4 Main phase drilling

Drilling is expected to commence with 17 ½” hole drilled through the initial 18” surface conductor. As well depth increases, drilling is temporarily suspended to add new drill pipe to the drill string, and when the drill bit becomes worn the entire string has to be lifted and disassembled before a new bit can be fitted and the whole drill string re-assembled and run-in again.

When the borehole reaches approximately 275m MD, the drill string will be removed and a new casing string – this time with a narrower 13 3/8” diameter will be run into the hole (inside the 18” casing) and cemented into place. This will seal the basalts (ALG), the Chalk (UWLF) and Hibernian Greensand Formation and isolate the shallow aquifers protecting them from further drilling activity.

Drilling will resume inside the 13 3/8” casing with a new smaller 12 ¼” drill bit and will then continue again until the borehole reaches approximately 850mMD (815mTVD), when a 3rd casing string, this time with 9 5/8” diameter will be run inside the 13 3/8” casing and cemented in place. This casing is to seal off the Mercia Mudstone Group, which overlies the target Sherwood Sandstone, it will provide protection against borehole collapse and make sure the optimum conditions are achieved for drilling through the target aquifer. The size of this casing string (9 5/8”) drives the entire casing design as the inside diameter needs to be big enough to accommodate the 8” pump that might be required to lift warm water to the surface and all the casings above this have to be successively bigger.

The final hole section will be drilled with an 8 ½” drill bit to penetrate the whole of the Sherwood Sandstone sequence and to tag the top 100m of the expected secondary aquifer (the Permian sandstones of the Enler Group). The final well TD is expected at 1507m (MD) (1470mTVD) in Borehole#1 and 1940m (MD (1730mTVD) in Borehole #2.

Once all the planned casings are installed, the shallow aquifer units are secure behind two separate casings (13 3/8” and 9 5/8”) but it is expected that the last bottom hole section will be left uncased. If the hole proves to be unstable during drilling (the uppermost part of the Sherwood Sandstone section can be poorly consolidated, as noted in nearby wells) then a perforated 7” liner could be run in. This liner would be left to rest on the bottom and will not be cemented as this would prevent the intended water flow from the target deep aquifer.

The well will be logged using a selection of downhole geophysical tools prior to each casing run. This is to obtain information on the geological section, to identify the rock types, their characteristics and the depths at which they are found and to check well integrity (e.g. a cement bond log). It is not currently planned to take core.

## 4.5 Drill Stem Testing

Drill Stem Tests (DSTs) will be undertaken on each well to establish the flow potential of the geothermal reservoir(s). The aquifer section will be isolated from the rest of the well bore with packers and the DST tool will then be opened to test the potential flow of water into the well and to measure the pressure within the aquifer. This will be followed by a shut-in period where the pressure is allowed to build-up again and this will give an indication of the performance of the aquifer.

## 4.6 Demobilisation

Upon completion of all the drilling, logging and testing (DST) operations, and with both boreholes temporarily suspended, the rig and ancillary equipment will be demobilised from the site in a reverse of the mobilisation process. Site restoration will be undertaken upon completion of Extended Well Tests (below) and upon evaluation of results to determine any future use for the boreholes.

## 4.7 Extended Well Tests

The final operational step is to run extended well tests. These will establish the production potential of the wells as well as the impact on the near well bore characteristics of the aquifer which will have been altered by the drilling process (skin factor). This would employ a separate smaller testing set up than that required for the DST and could comprise a series of separate tests including some that repeat those initially included in the drill-stem tests:

- Buildup test (or pressure buildup test), where the well is initially produced and then shut in to monitor pressure increase.
- Drawdown tests including step tests and constant rate pumping tests.

- Injection tests where fluid is introduced to the reservoir and then the well is shut in to analyse the pressure response.
- a combined abstraction and re-injection test to mimic a possible future doublet implementation.

4.8 Site restoration will be undertaken upon demobilisation of the well testing unit, the drill area will be restored to previous land use (agricultural grassland) and profile, back to a smaller retained hardstanding area around the well-heads, using the excavated top-soil and sub-soils/rock. This new smaller retained area will be fenced off, with locked gate access. All engineering materials (liner, geotextiles, hard-core, drainage) outside of the retained area will be removed and transferred off site to a licensed waste/recycling facility.

# 5.0 Well Cost Estimates

## 5.1 Introduction

The analysis below includes site investigation and subsequent preparation, as well as the drilling and testing of the planned two geothermal boreholes as outlined above. The proposed well designs have been tested against the designs for other, locally drilled deep boreholes (Annaghmore, Ballinlea-1, Ballymacilroy-1, Ballynamullan-1, Ballynure-1, Islandmagee-1, Langford Lodge and Woodburn-Forest-1). The designs have been discussed with the Geological Survey of Northern Ireland (GSNI) and their feedback has been incorporated.

Having established an outline design, identified possible rig requirements and created initial site designs, the associated costs have been generated based upon the expertise of internal colleagues involved in developing similar projects and colleagues operating in the O&G sector internationally. The well costs costs are expected to range from £6.20mm to £9.96mm. The principal cost elements (CE) are outlined below and in Table 1.

## 5.2 CE 0 Full Well Design

Once a final scope is agreed for the boreholes, a full well design should be completed by a qualified well engineer. This will make sure all design/engineering issues are properly addressed to allow the safe and effective progress of subsequent drilling operations (it should for example address pore pressure analysis, detailed casing design, hydrocarbon risk assessment and mitigation measures). This work is currently estimated to cost £10k-£14k.

## 5.3 CE 1 Site Preparation

The site investigation, well pad design and construction costs are based on Tetra Tech knowledge of similar projects and our current understanding of the site. At the time of writing, no ground-investigation work has been undertaken to date and the outlined site layout is currently generic as detail of rig components will not be identified until completion of any tender process and the final rig selection. This work is currently estimated at £200k but preliminary Ground Investigation work is scheduled in March 2025 which should provide greater clarity on costs.

## 5.4 CE 2 Conductor Drilling

As described above, it is expected that a water well rig will be mobilised to drill the top-hole sections for both boreholes from surface to approximately 20m. This work is currently estimated at £50k-£70k.

## 5.5 CE 3 Rig Mobilisation

There are no rigs with sufficient capacity to drill boreholes of this depth and complexity on the island of Ireland. The rig will have to be mobilised from GB or Europe. Distances range between 1500km and 3000km (Figure 7), costs may exceed £1.5mm and comprise >15% of the final cost.

## 5.6 CE4 Rig Operations (Borehole Drilling)

The principal component of the cost is the operation of the drilling rig, comprising 70-80 % of the total. This cost is made up of the daily cost for the plant and associated equipment (the rig itself plus ancillary services including mud, mud logging, wireline logging, testing etc) and the number of days required to complete all drilling operations including the logging and testing.

We believe that the combined rig cost (known as spread-rate) may range between £50k to £75k per day, although prior to tendering this carries high uncertainty, perhaps +/-40%.

We have estimated the number of days of rig time required to drill the wells based on a simple analysis of time required to drill similar deep wells in Northern Ireland (Figure 8). This suggests 95 days comprising:

- 24 days drilling Borehole#1
- 58 days drilling Borehole#2
- 2x1 days logging
- 2x3 days DST
- 5 days rig up/move/rig down

The rig and associated costs are therefore likely to be in a range from £4.7mm to £7.1mm. This represents the bulk of the total costs but also generates the bulk of pricing uncertainty.

## 5.7 CE 5 Extended Well Tests

Based upon Tetra Tech experience on Northern Ireland, the extended well tests are expected to cost between £70k and £90k.

## 5.8 CE 6 Well Construction (Tubulars, Well Heads)

Conductors/casings and liners are likely to cost £500k (plus well heads and pumps). Most of this cost is driven simply by steel prices. It should be noted that half of this is for the optional 7” liner (both wells) which may not be required on either borehole if the formation is sufficiently robust for the aquifer sections to be left open-hole.

## 5.9 CE 7 Supervision and Admin

A small drilling supervision team will be required during operations, this is assumed to comprise one senior drilling engineer, a senior hydrogeologist plus admin support and travel. Over 95 days of operations this is expected to cost in the region of £200k.

## 5.10 Exclusions

It should be noted that there is no provision for funding any subsequent connection of geothermal wells to any buildings, or the internal infrastructure within them (*e.g*. heat pumps, plant rooms or building modifications).

### Table 1 Greenmount Deep Geothermal Boreholes, Preliminary BoQ

| Cost Element | | Total (£k) low | high |
|---|---|---|---|
| **0.0** | **Full Well Design** | | |
| | well engineering consultants | 10 | 14 |
| **1.0** | **Site Preparation** | | |
| 1.1 | site investigation (GI) | 12 | 15 |
| 1.2 | Earthworks specification | 3 | 3 |
| 1.3 | Archeological Supervision | | |
| 1.4 | Slope Stability Assessment | | 7 |
| 1.5 | pad construction (incl professional/survey fees) | 135 | 135 |
| 1.6 | membrane installation | 26 | 26 |
| 1,7 | pad reinstatement / borehole development TBC | 18 | 18 |
| **2.0** | **Conductor drilling rig (TBC)** | | |
| 2.1 | well cellars | 4 | 4 |
| 2.2 | top hole drilling | 50 | 70 |
| **3.0** | **Rig Mobilisation** | | |
| 3.1 | Mob/Demob | 600 | 1660 |
| **4.0** | **Rig Operations** | | |
| 4.1 | Day rate / turn-key | 1900 | 2375 |
| 4.2 | Combined Spread Rate | | |
| | Mud Logging/Wireline/Testing/DST/Completion | 2850 | 4750 |
| **5.0** | **Extended Well Test** | | |
| 5.1 | Test equipment and fuel | 70 | 90 |
| **6.0** | **Well Construction** | | |
| 6.1 | Conductor/Surface 18" casing | 9 | 9 |
| 6.2 | 13 $^{3}/_{8}$" casing | 75 | 75 |
| 6.3 | 9 $^{5}/_{8}$" casing | 209 | 209 |
| 6.4 | 7" liner (optional) | | 250 |
| 6.5 | Well head | 12 | 16 |
| 6.6 | Completion Equipment (subsurface pumps and risers) | 10 | 20 |
| **7.0** | **Supervision and Admin** | | |
| 7.1 | Operations support (drilling supervision & admin) | 203 | 203 |
| | **Total** | £6,202 | £9,960 |

# 6.0 Discussion

This analysis suggests total cost to complete preparations at the site and both drill and complete the two geothermal boreholes is likely to be in the range £6.20 - £9.96mm. Key points to note include:

- The costs presented 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 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. For example, ground investigation at the site could require additional works to construct an appropriate drilling compound and/or subsurface drilling issues could require significant additional cost and time.
- 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. This is illustrated on Figure 9. All the rigs outside the UK are between 1500 and 3000km distant.
- The cost of the provisional 7" liner at £250k is also significant.

We have 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 €14-15mm but this is from 2017 and for more complex wells with extensive horizontal sections.

A final option for discussion is the option to drill a narrow diameter cored stratigraphic borehole in advance of the borehole doublet. The purpose of this borehole would be to validate the current ground model, give confidence that the expected ground conditions are present and allow the cost of the borehole doublet to be refined. The cost of drilling a single stratigraphic borehole could be in the order of £1m. Planning permission may not be required for this stratigraphic borehole as it could probably be drilled as a mineral proving borehole under permitted development rights, but it would be more complete to include it as part of the proposed planning application. The enabling works, construction, testing and decommissioning (if relevant) of the stratigraphic borehole should be afforded further consideration as part of the deep drill planning application.

# 7.0 Summary and Conclusions

This report provides a high-level summary of cost estimates to drill and test the two deep geothermal boreholes planned as part of the GeoEnergy NI project at Greenmount, Co. Antrim. The project is still at an early planning stage. Previous work on the geology, geophysics and expected geothermal characteristics of the site allow construction of outline designs for the wells which can be costed but there remains significant uncertainty around both the likely costs and lead time for securing a rig.

# 8.0 References

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# Figures

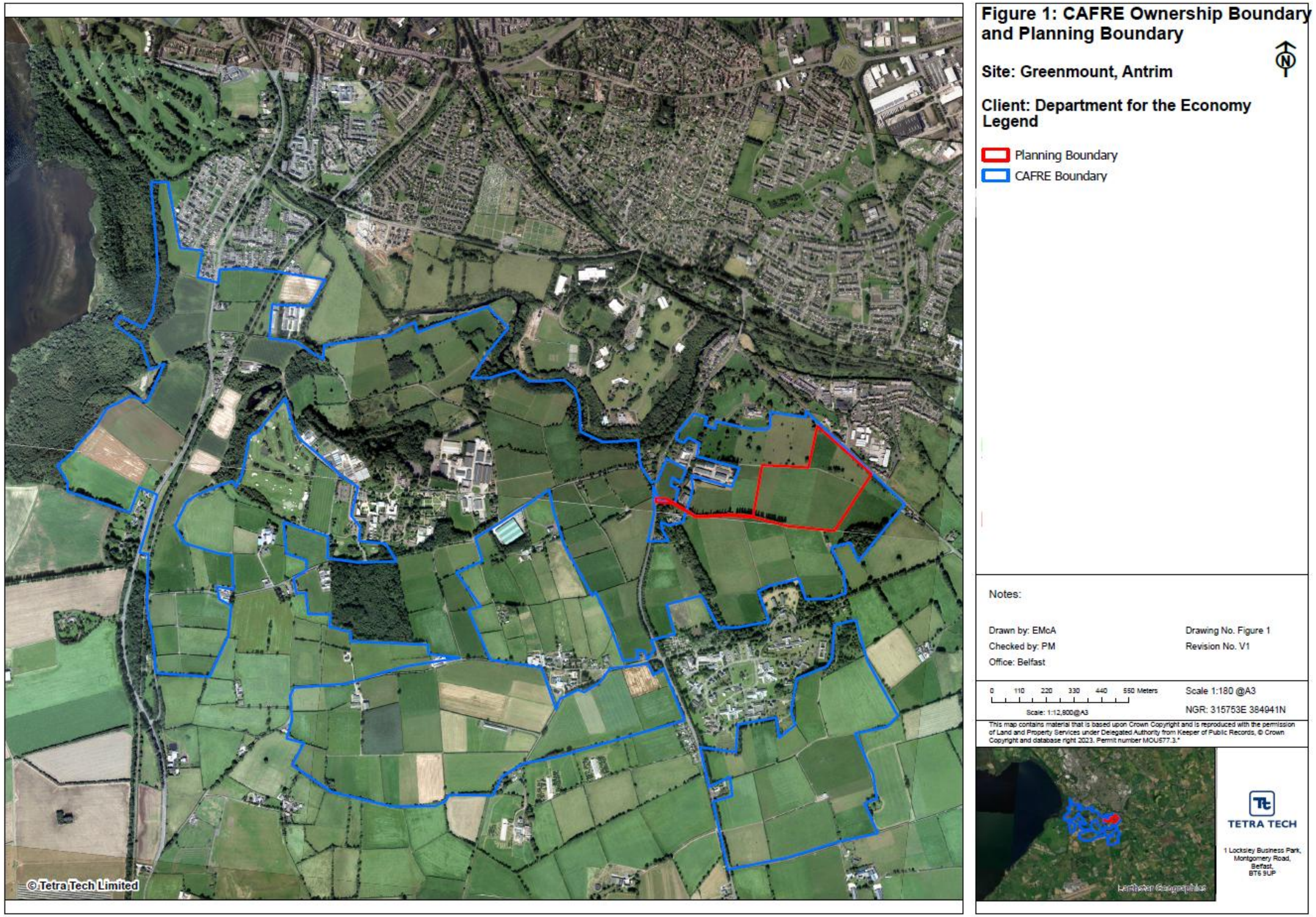


**Figure 1: CAFRE Ownership Boundary & Planning Boundary**

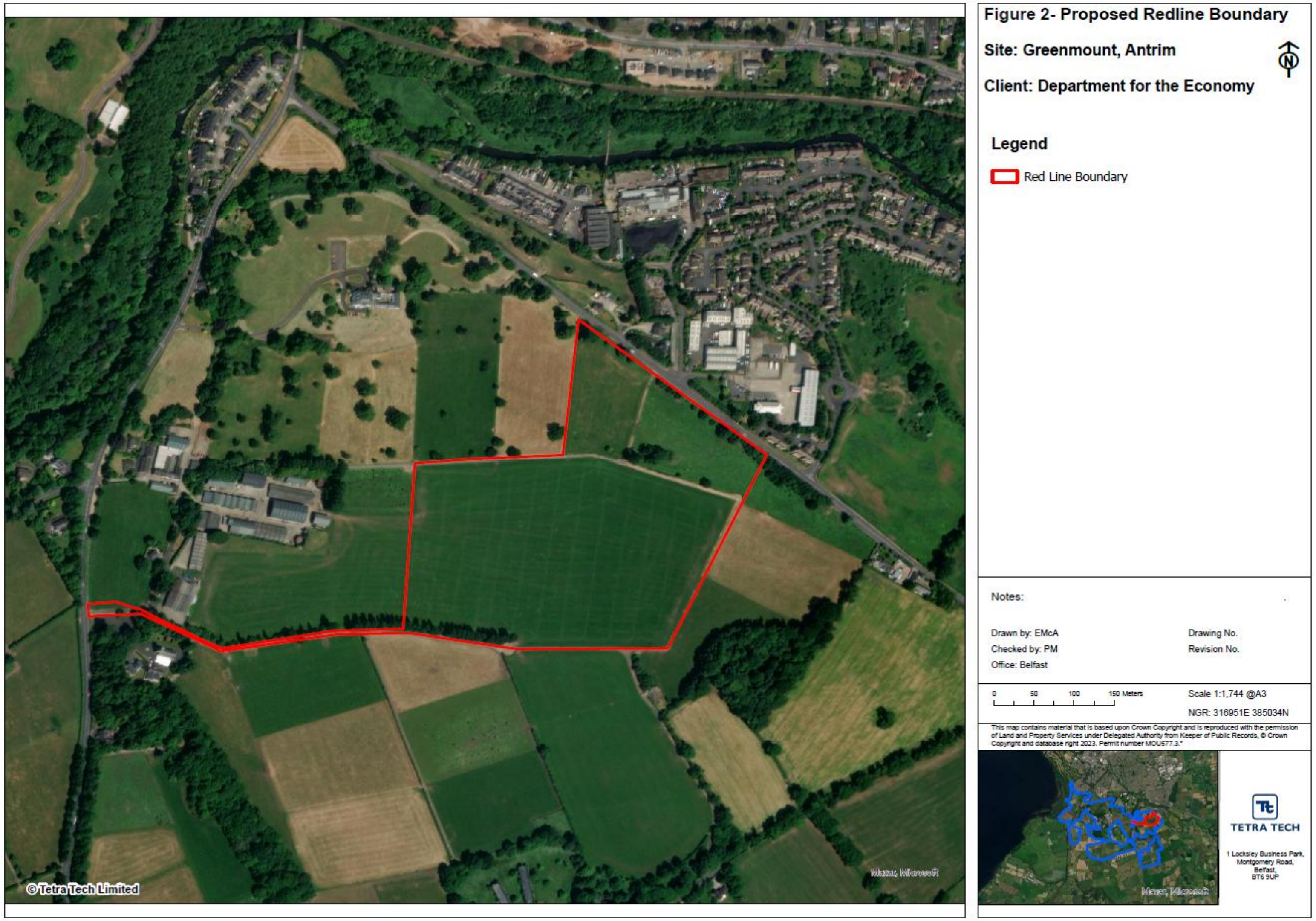


**Figure 2: Proposed Redline Boundary**

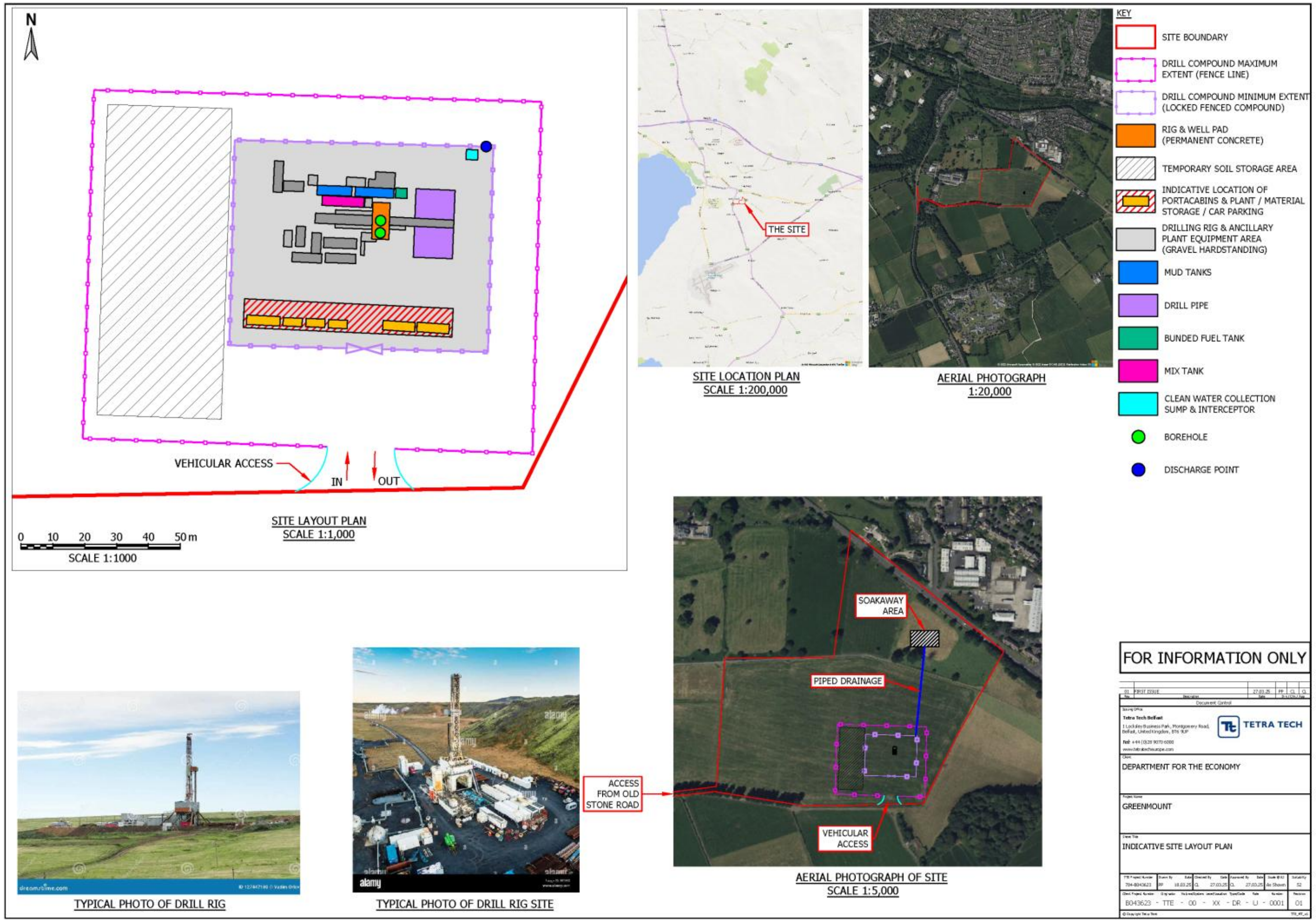


**Figure 3: Possible rig site layout with rig images**

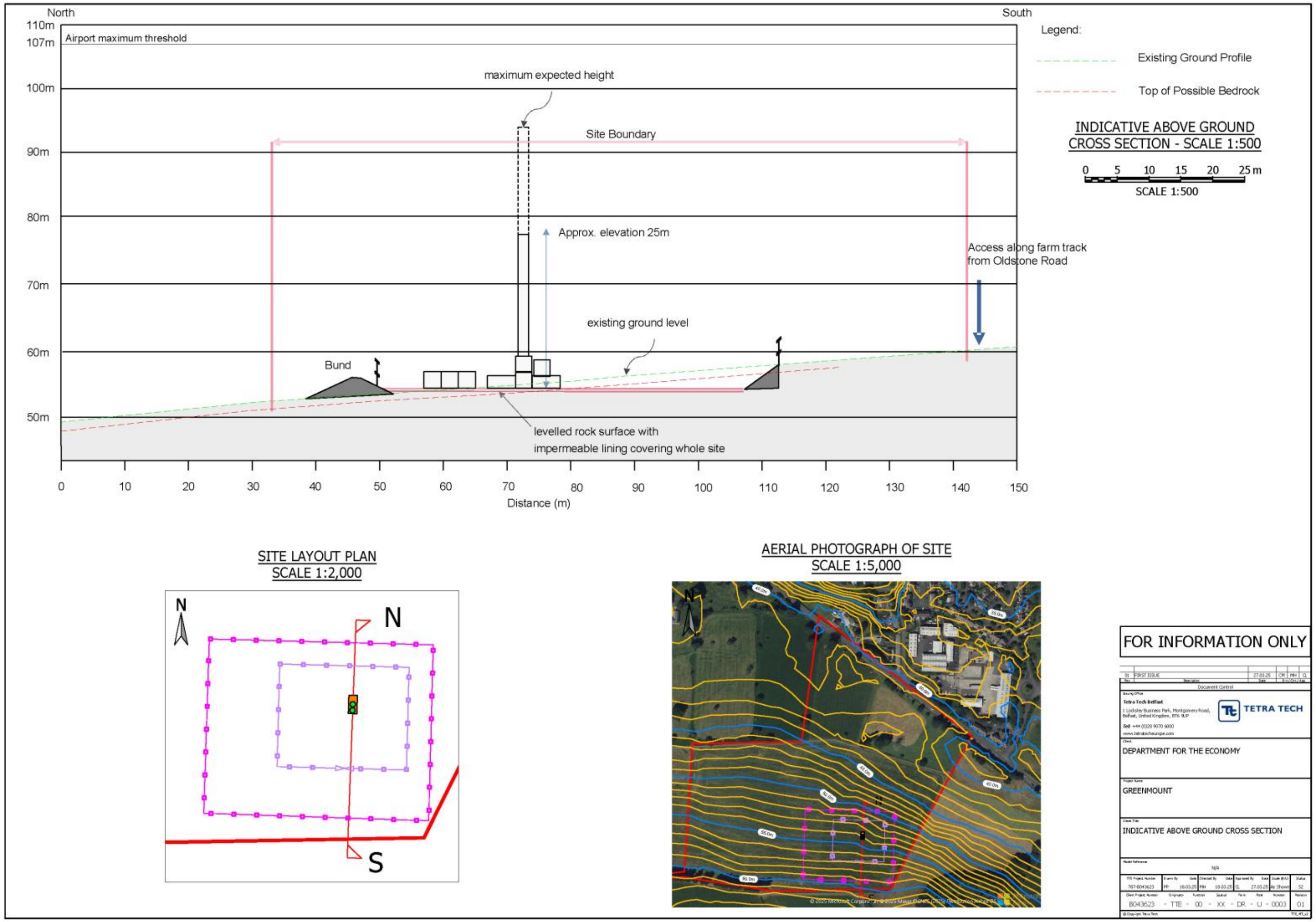


**Figure 4: NS Profile of proposed rig compound  (generic rig design) with Rig Site Elevation (inset)**

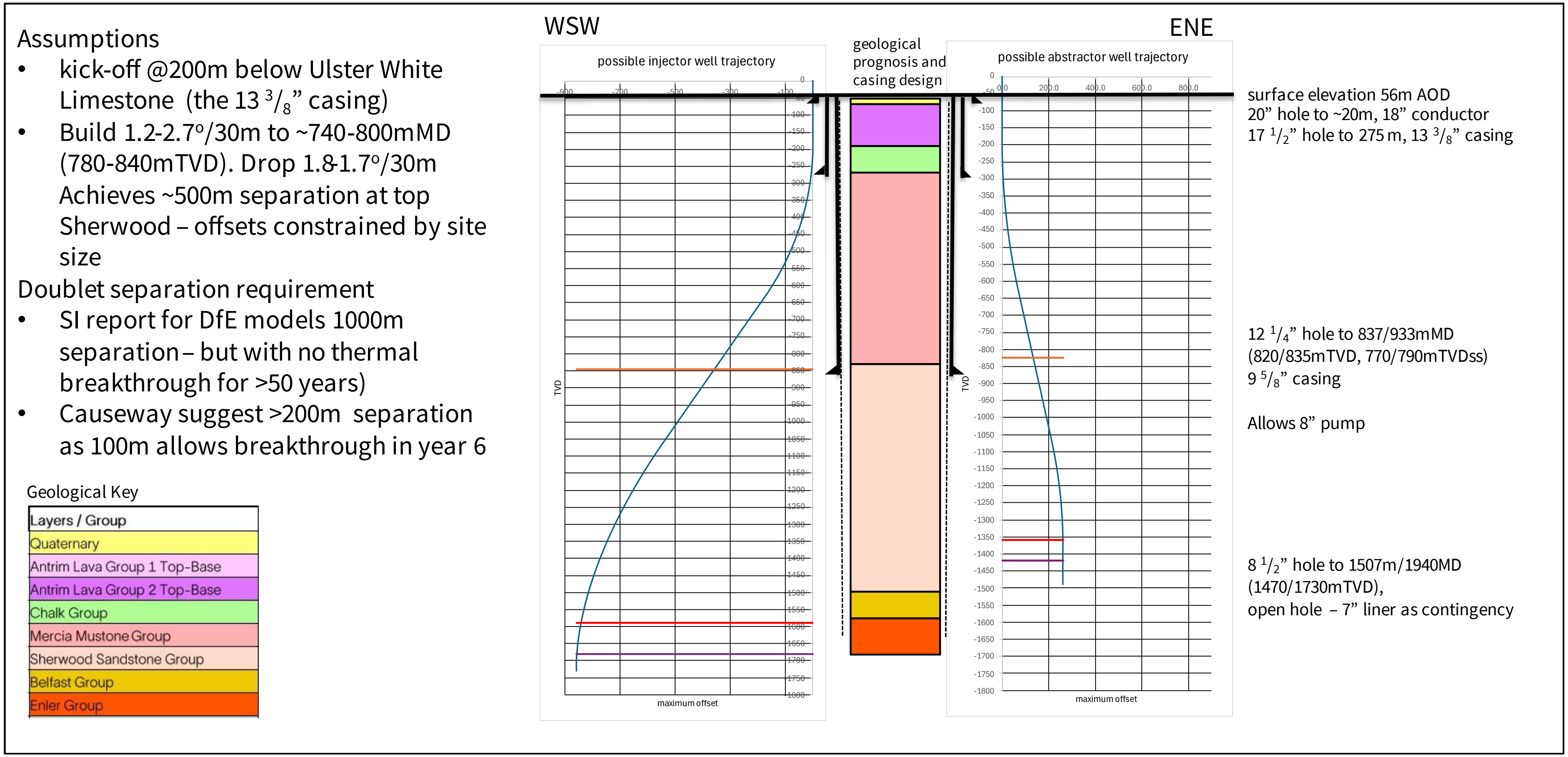


**Figure 5: Initial Prognosis, well trajectories and casing plans**

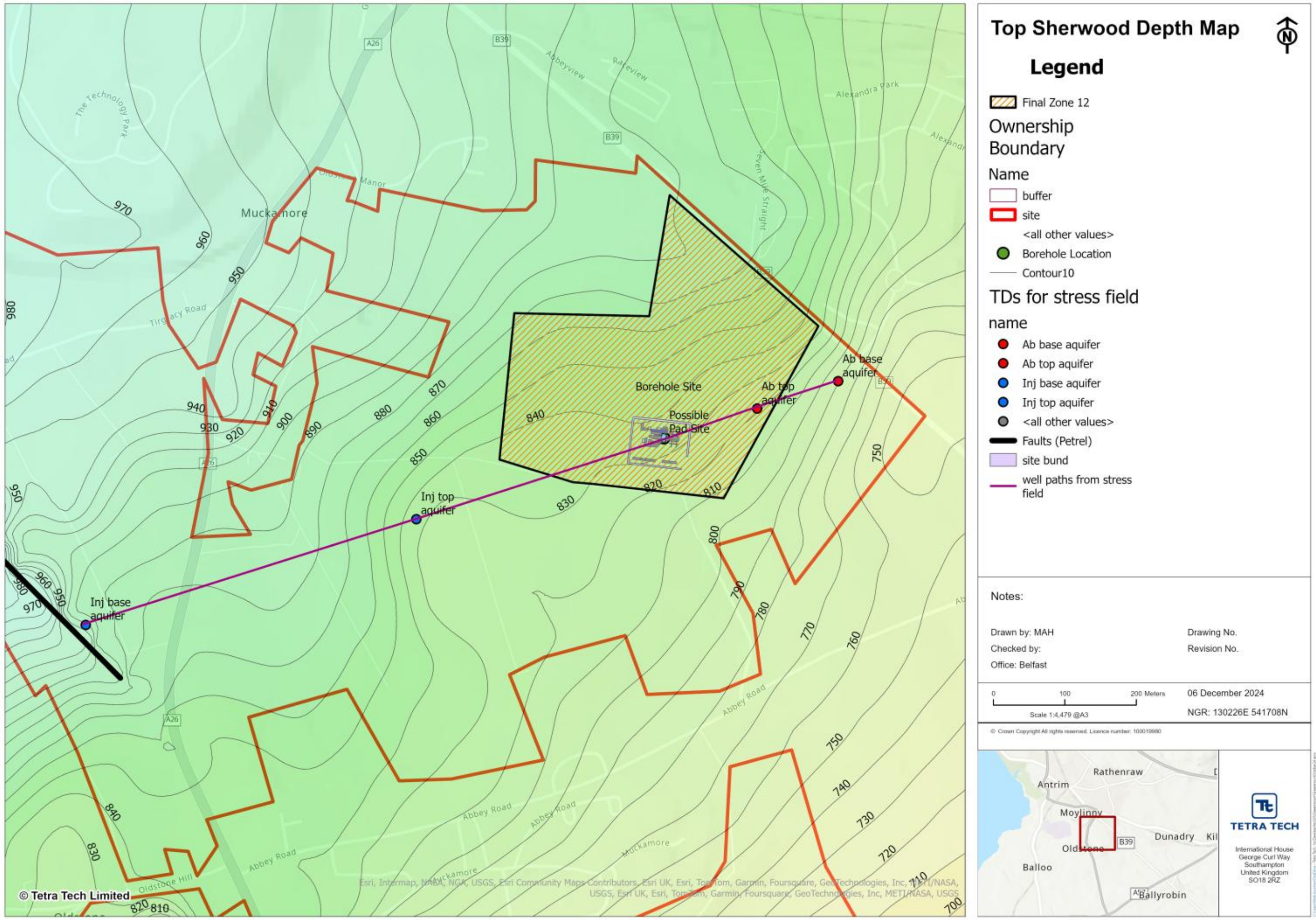


**Figure 6: Possible Well Trajectories and locations of aquifer penetrations**

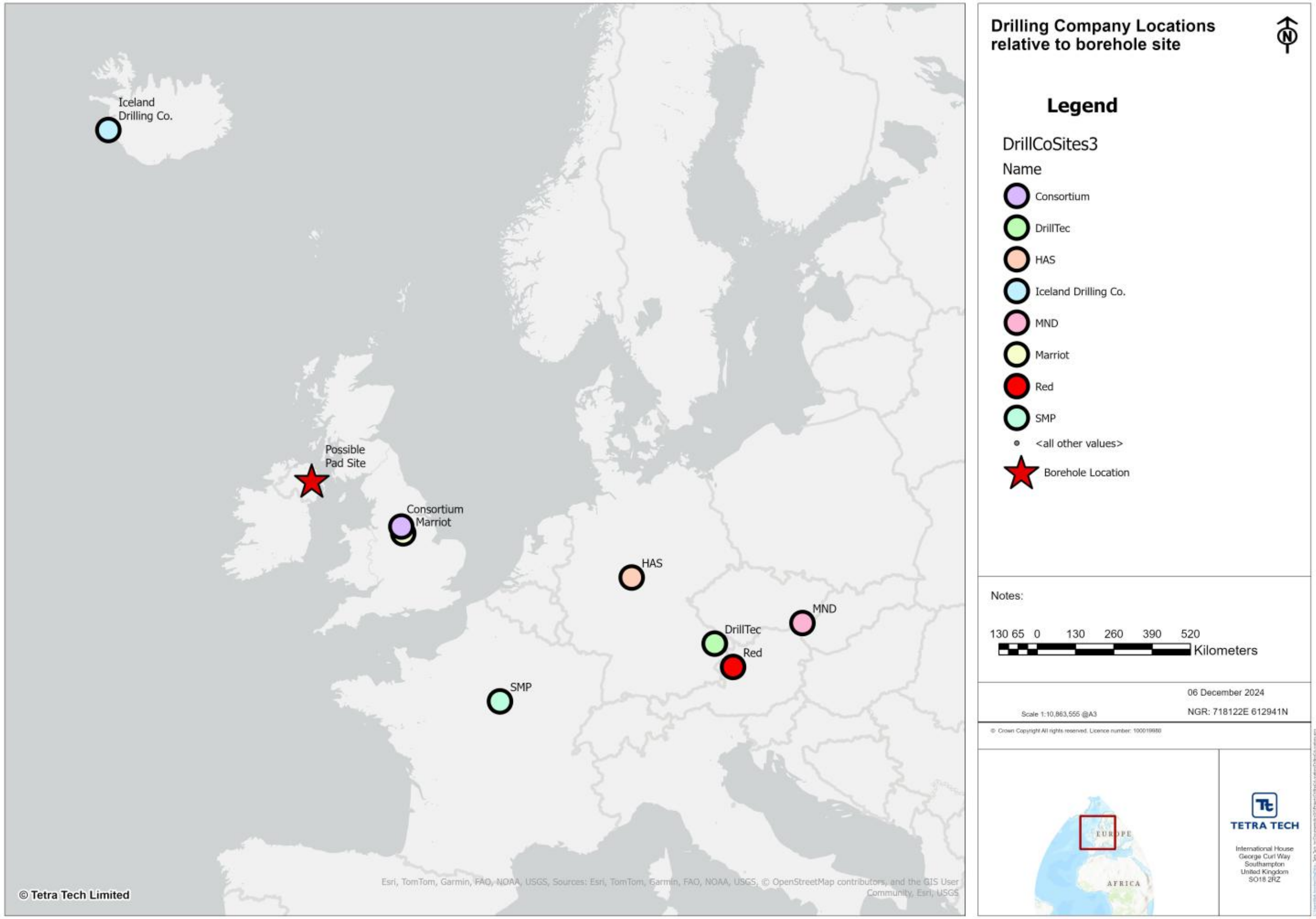


**Figure 7: Location of possible drilling contractors and rigs**

Annaghmore

- Spudded 13th Feb '93 TD 11th March @ 5100' (1554m) in Permian Sst (top Sherwood @ 1660' (506m) (26 days) but issues with well head – prognosed 18 days)

Ballynamullan

- Spudded 3rd October '94 TD 19th October @ 4849' (1478m) in Permian Sst (top Sherwood @ 2300' (700m) (16 days) – logged on 20th Oct DST 1 on 21st October

Ballytober

- 25 days from spud to TD 1282 m

Newmill-1

- 76 days from spud to TD 1981 m

Woodburn Forest No. 1

- Spudded 15th May, TD 13th June, logging completed on 16th June, well completed on 18th June and rig released on 21st June 35 days spud to TD (planned at ~2000m depth, VSP implies 1750)

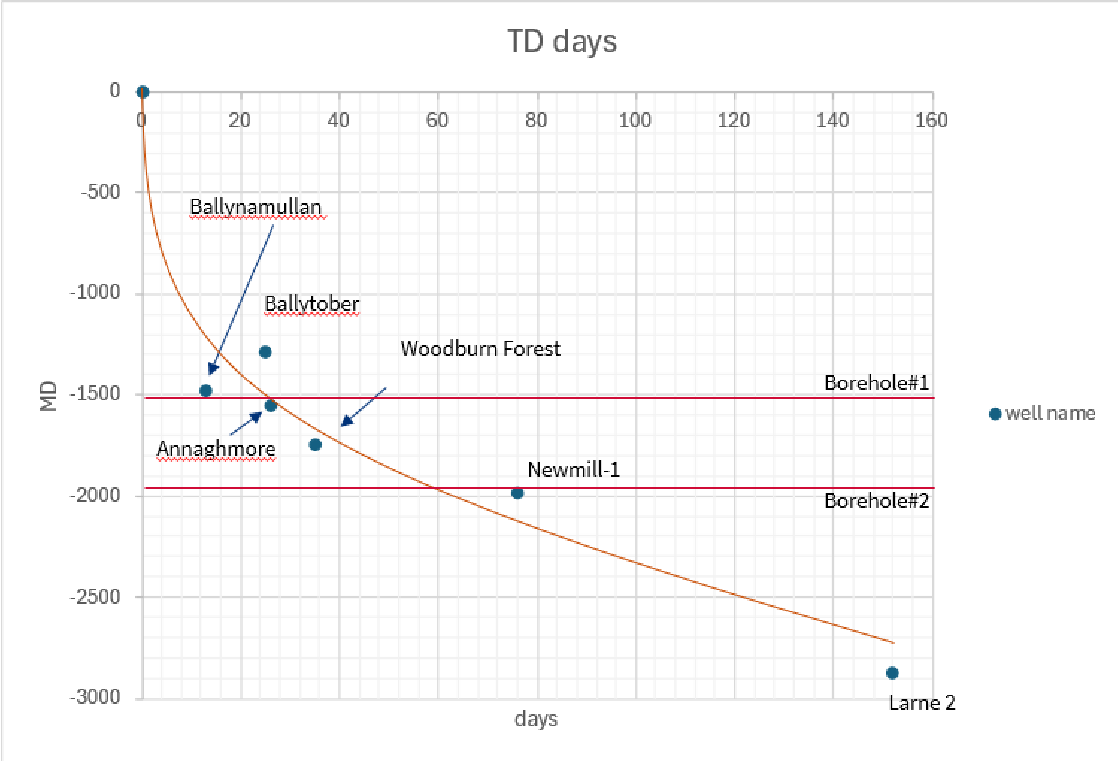


**Figure 8: Possible Well Duration**