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Environmental baseline characterisation and monitoring borehole GGA03r, UK Geoenergy Observatory, Glasgow

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UK GEOENERGY OBSERVATORIES PROGRAMME

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Environmental baseline characterisation and monitoring borehole GGA03r, UK Geoenergy Observatory, Glasgow

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Front cover

Cleaning borehole GGA03r and taking samples (to left of borehole)

Bibliographical reference

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Summary

This report and accompanying data release describe the 'as-built' borehole GGA03r at the UK Geoenergy Observatory in Glasgow, as well as summarising hydrogeological testing and an initial geological interpretation.

Environmental baseline characterisation and monitoring borehole GGA03r at the UK Geoenergy Observatory in Glasgow is screened across sandstone below rockhead and above the Glasgow Upper coal mine working. Hydrogeological evidence from test pumping indicates that the borehole is low yielding. There is a hydrogeological data logger installed in the borehole.

1 Introduction

Drilling of the environmental characterisation and monitoring baseline borehole GGA03r at Cuningar Loop in Rutherglen, Greater Glasgow, took place between 20th June and 25st October 2019 (start of drilling to casing installation date). The borehole targets a sandstone beneath rockhead and above the Glasgow Upper mine working, with the slotted screen at -26.96 to -29.77 m relative to Ordnance Datum.

The borehole was drilled as part of a set of six mine water*, five environmental baseline and a seismic monitoring borehole as part of the UK Geoenergy Observatory in Glasgow. Further details of the purpose and planned infrastructure at the Observatory are described in Monaghan et al. (2019) and a geological characterisation of the area is provided in Monaghan et al. (2017).

This document and accompanying data files provides the definitive information on the 'as-built' borehole infrastructure.

- Table 1 and Figure 1 provide a summary of the borehole. Figure 1 is also included in the information release [*Summary_BGS_Log_GGA03r.pdf*]
- Appendix A lists the files making up the information release.

1.1 CITATION GUIDANCE

Any use of the data should be cited to:
DOI: https://dx.doi.org/10.5285/7971dbc3-d4a3-4f74-90a9-89b46d39ad49 K Shorter, V Starcher, H F Barron, K Walker-Verkuil, A A Monaghan. 2020. UK Geoenergy Observatories Glasgow Borehole GGA03r Data Release
and this report cited as:
SHORTER K, STARCHER V, BARRON H F, WALKER-VERKUIL K, MONAGHAN A A 2020. Environmental baseline characterisation and monitoring borehole GGA03r, UK Geoenergy Observatory, Glasgow. British Geological Survey Open Report, OR/20/023.

* Five boreholes were completed as mine water boreholes and one was completed as a sensor testing borehole

Table 1 GGA03r as-built data

Borehole number	GGA03r	
Site	GGERFS01	
Easting (British National Grid)	262309.311	
Northing (British National Grid)	662860.227	
Drilling platform level (metres above Ordnance Datum AOD)	10.95	
Drilling started	20/06/2019	
Final casing installed	25/10/2019	
As-built borehole start height or datum (top Boode casing flange, metres AOD)	10.04 (recorded as 10.037)	
Installation details		
Borehole detail	**Depths (drill length from drill platform level, metres)**	**Diameter size**
Made ground casing	0.0 – 16.3	16” (406.4 mm OD x 381.2 mm ID)
Rockhead casing	0.0 – 31	10 3/4” (273.1 mm OD x 252.7 mm ID)
Boode Well (BW) casing	0.0 – 37.91	165 mm OD x 146 mm ID
BW Slotted pipe with pre-glued gravel pack	37.91 – 40.72	191 mm OD x 146 mm ID
BW casing sump	40.72 – 41.72	165 mm OD x 146 mm ID
Geological details	**Depths (drill length from drill platform level, metres)**	**Depths, relative to Ordnance Datum (m)**
Base of made ground	8.3	+2.65
Base of superficial deposits	27.4	-16.45
Final drilled length	41.72	-30.77
BGS SOBI reference number	NS66SW BJ 3757	BGS ID 20693598

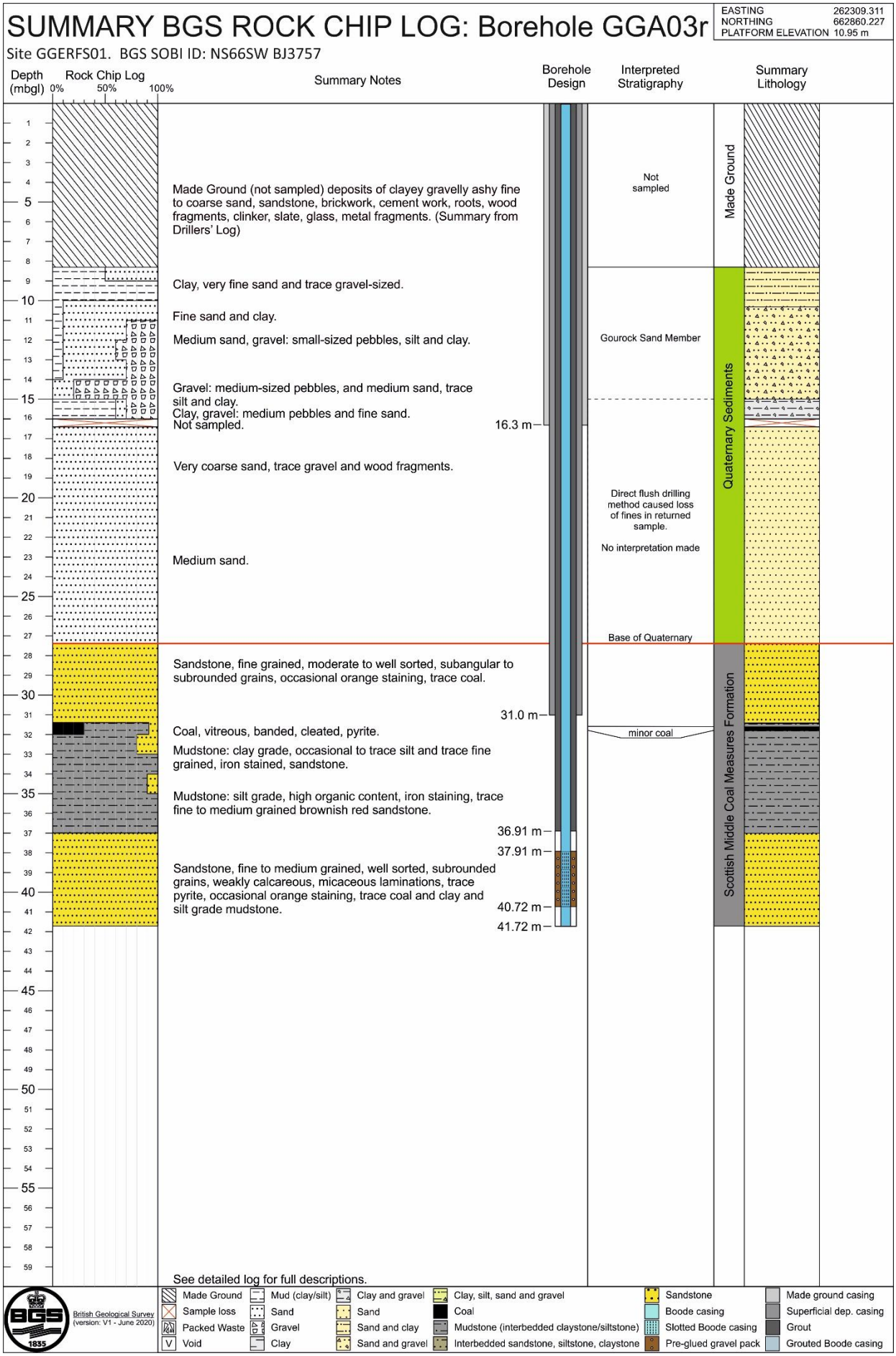

Figure 1 **GGA03r summary log based on rock chip returns**

1.2 AS-BUILT BOREHOLE LOCATION

Borehole GGA03r is part of the UK Geoenergy Observatory: Glasgow Geothermal Energy Research Field Site (GGERFS) located on the southern side of the River Clyde in Rutherglen, South Lanarkshire, four kilometres south-east of Glasgow city centre (Figure 2).

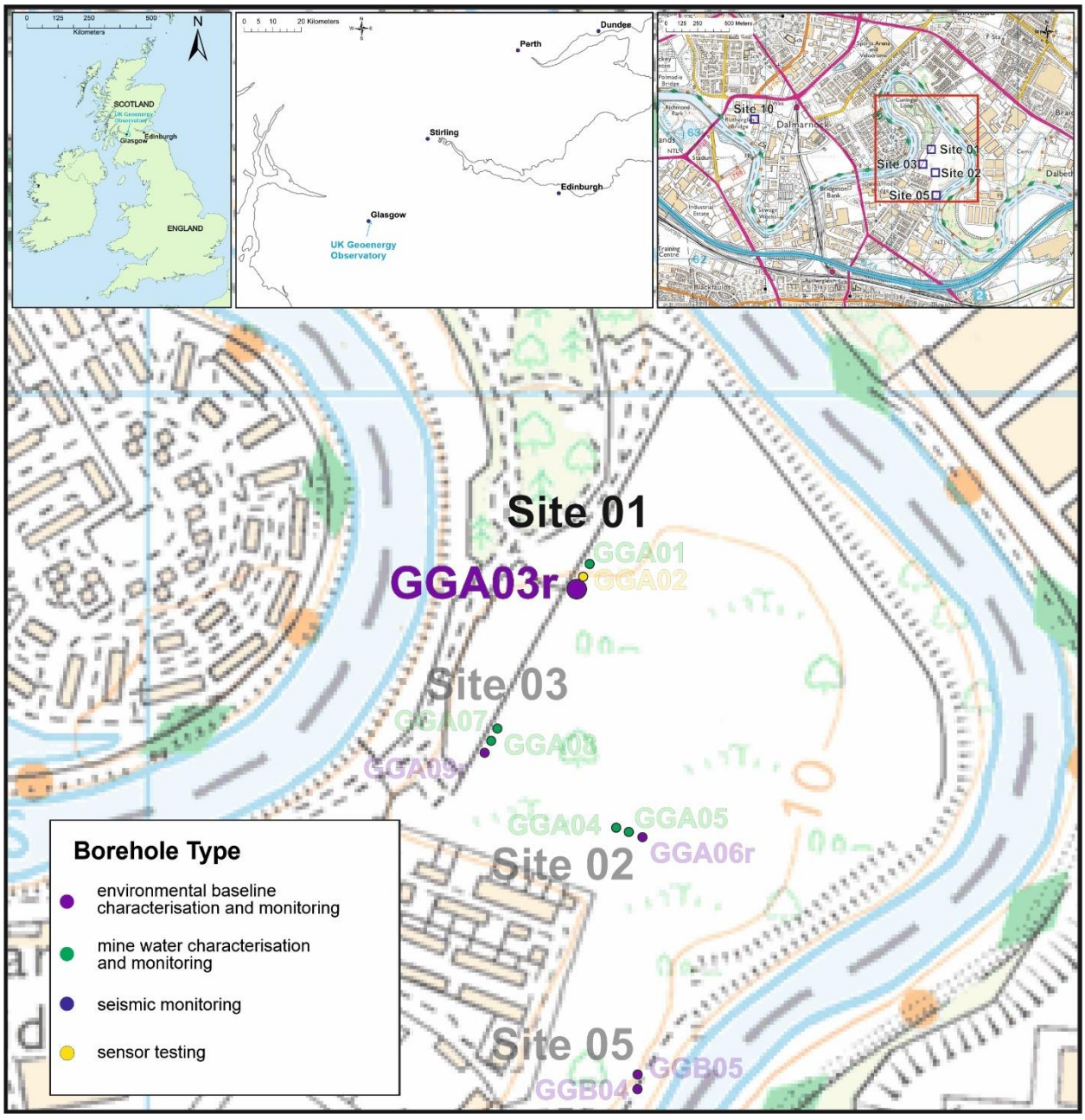

Figure 2 Location map of borehole GGA03r, UK Geoenergy Observatory in Glasgow. The other mine water and environmental baseline boreholes are shown for reference. Contains Ordnance Survey data © Crown copyright and database rights. All rights reserved [2020] Ordnance Survey [100021290 EUL].

1.3 DRILLING AND AS-BUILT LENGTHS AND HEIGHTS

Borehole drilling took place from a built-up gravel platform, with the reference datum for drilled depth (measured in metres below ground level; mbgl) being the drilling platform ground level (measured in metres above Ordnance Datum; m AOD; Figure 3). All drillers' logs, sample depths, and BGS rock chip logs are referenced to the drilling platform level. After drilling had been completed the borehole casings were cut down and a manhole chamber was installed (Tables 2,3).

After the hydrogeological test pumping had been completed, the borehole head works were installed in the manhole chamber. The as-built borehole therefore has a different start height or reference datum level, which the top of the blue Boode casing flange (Figure 3). Depths down the borehole can be expressed as lengths from the top Boode casing, or relative to Ordnance Datum (Tables 2,3).

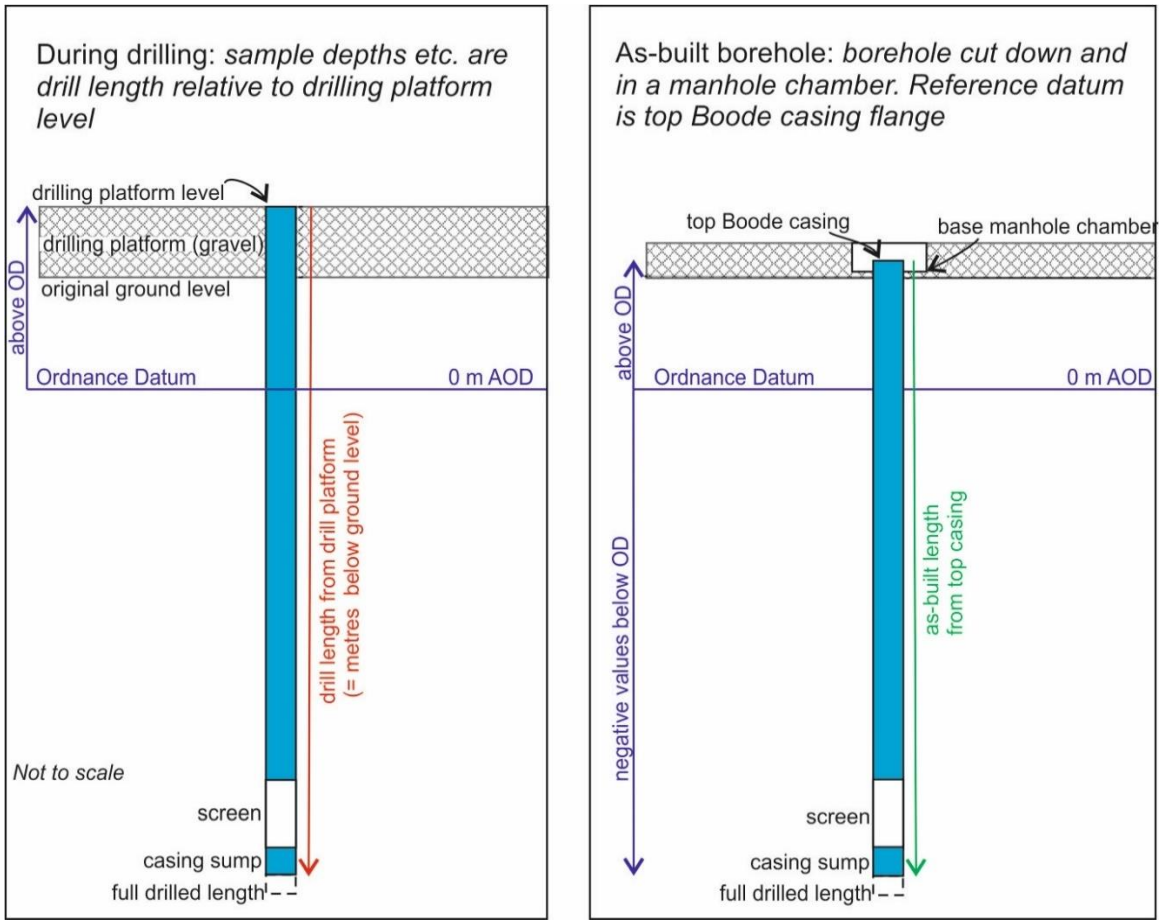

Figure 3 Images summarising the datums and depths/lengths/heights during drilling (left) and as-built (right)

Table 2 Summary of start heights and datums used for GGA03r

Stage	Borehole start height/ reference datum used (m AOD)	Used in
Drilling platform level – built up gravel platform	10.95	Drillers and BGS logs, sample depths
As-built borehole start height (top Boode casing flange)	10.04 (recorded as 10.037)	Reference datum for future Observatory users
Conversion Rock chip and log sample depths – to convert from drill length to beneath as-built borehole start height		As-built depth below start height = drill length – (10.95- 10.04) m *i.e* As-built depth below start height = drill length – (0.91) m

2 As-built borehole summary

The Glasgow Geoenergy Observatory boreholes have been designed for a range of scientific research purposes over a 15-year lifetime, with 2 sets of sensor cables installed on the outside of the bedrock casing (mine water boreholes). As such, their construction is not typical of mine water or environmental monitoring boreholes that would be installed for commercial schemes.

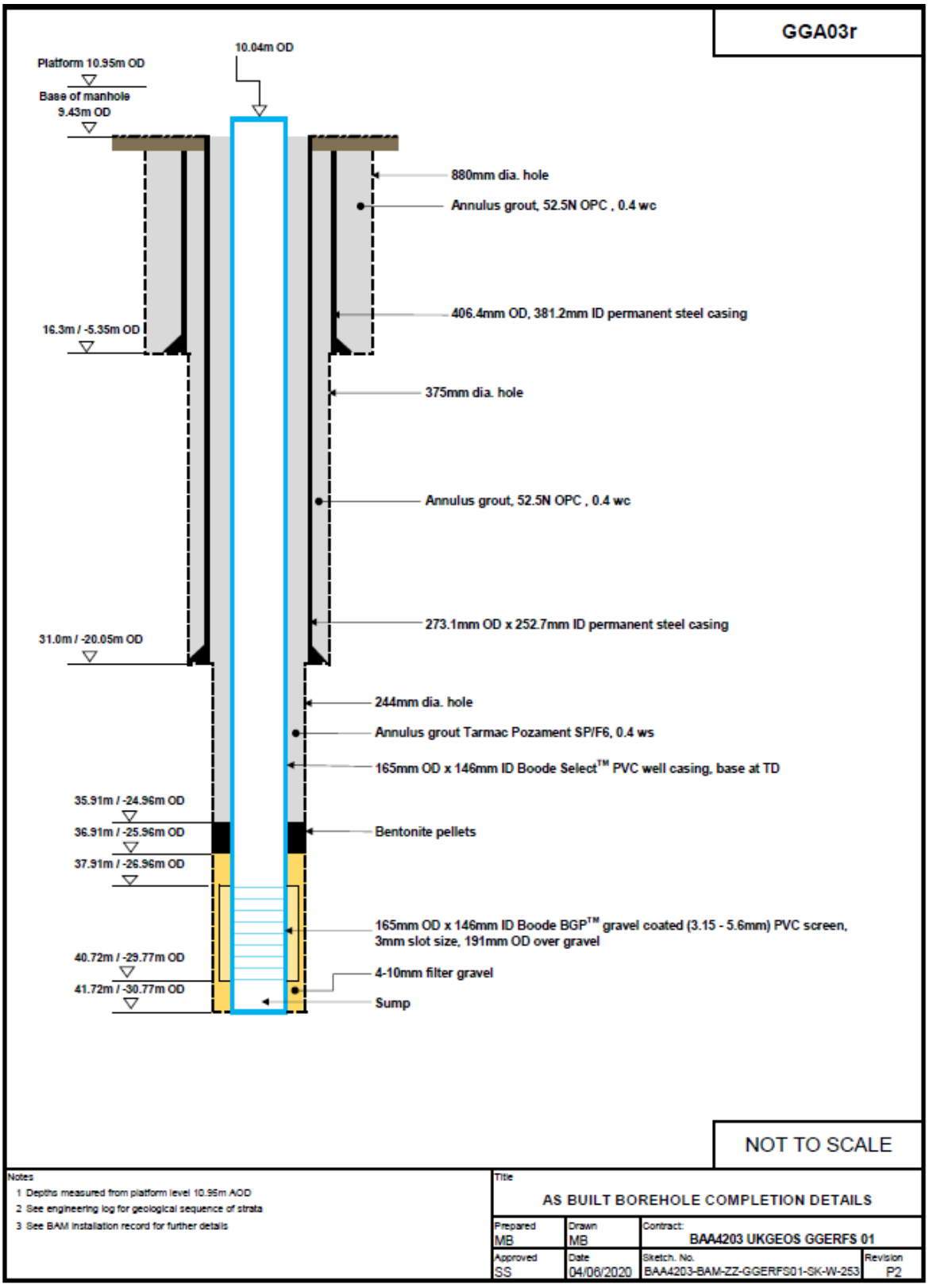

Figure 4 As-built borehole schematic for GGA03r

2.1 BASIS OF DESIGN

The basis of the GGA03r borehole design was as follows;

i. Separate borehole casings were installed through the made ground, superficial deposits and bedrock sections of all the UK Geoenergy Observatory boreholes at Cuningar Loop, with the annulus of the different casing sections grouted before the next section was drilled. This was done to prevent the mixing of groundwaters of different quality, which could occur if vertical flow paths were created during drilling (important to avoid from both an environmental quality and scientific research perspective).

ii. The borehole is screened only across the target interval (sandstone) and is fully sealed above the screen, so that all hydrogeological observations from this borehole relate only to this interval.

iii. A screen slot size of 3 mm was used, in the sandstone, with 3.15 to 5.6 mm sized bonded gravel pack attached.

iv. The borehole sump was included to catch any fines that enter through the slotted screen.

v. Gravel filled the remaining annular space around the gravel pack and was overlain by a bentonite layer (35.91 – 36.91 mbgl) to ensure a good top seal. Once the bentonite had set sufficiently (24 hours) then the annulus was grouted with a SP/F6 mix.

Table 3 Summary of heights for as-built borehole features for GGA03r

Feature	Depths (drill length from drill platform level, metres)	Height (m) relative to Ordnance Datum	As-built length (m) down hole from top casing datum (top Boode flange)
Top slotted screen	37.91	-26.96	37.0
Base slotted screen	40.72	-29.77	39.81
Base installed casing sump	41.72	-30.77	40.81

3 Drilling, casing, annulus grouting and testing methodology

Borehole GGA03r was drilled and cased in separate sections for made ground, superficial deposits and bedrock. In between the sections the drill rig moved off to complete sections of other boreholes on site, thus the overall timescale for the borehole appears much longer than would be expected (Tables 1, 4).

Table 4 summarises the steps involved in the drilling of GGA03r, further details are given in the borehole information summary at the end of the Driller's log file (see section 4.1). Other points of note include

- Water flush was used throughout the drilling of the superficial deposits and bedrock sections
- The drilling technique in the made ground section was piling rig with auger. In the superficial deposits rotary open hole with direct flush was used. The bedrock section used rotary open hole with reverse circulation.
- Fluid and rock chip samples were taken from the superficial deposits and bedrock sections for academic researchers and rock chip samples were taken for archiving in the BGS National Geological Repository.

Table 4 Summary of drilling, casing, grouting and testing of GGA03r. All depths are metres below drilling platform level (mbgl).

Drilling and installation summary:	
20/06/2019	Drilled and installed made ground and superficial casing with BAM piling rig to 16.0 mbgl, with a 34 ¾" (880 mm) auger. Base made ground was recorded at 8.3 mbgl.
21/06/2019	Made ground and superficial casing grouted. Casing (406.4 mm OD) installed to 16.3 mbgl due to sinking into superficial deposits.
04/07/2019	Drilled superficial deposits to rockhead with Fraste rig from 16.0 mbgl to 31.4 mbgl with a 14 ¾" (374 mm) tri-cone bit Section drilled with direct flush as a stuffing box was used for gas control. This method provided poor quality samples – the drilling method did not allow for easy identification of till or rockhead.
05/07/2019	Setting up site to install 10 ¾" (273.1 mm OD) superficial to rockhead casing and grout
08/07/2019	Grouting base of casing, casing was lifted so that casing shoe was grouted
09/07/2019	Install 10 ¾" (273.1 mm OD) superficial to rockhead casing and grout the casing annulus Drill rig moved to another borehole
15/08/2019	Drilled to target screened interval depth with Fraste rig from 31.4 mbgl to 41.72 mbgl, with a 9 ⅝" (244 mm) tri-cone bit. This was the total depth for the borehole. Seal: 35.91 – 36.91 mbgl bentonite plug Screen: 37.91 – 40.72 mbgl 3 mm slotted Boode casing with 3.15 to 5.6 mm bonded gravel pack Sump: 40.72 – 41.72 mbgl Due to end cap of Boode casing not present on site, a 30 cm grout plug was placed at base of sump casing.
16/08/2019	Boode casing annulus grouted with Pozament® cement SP/F6 and completed
24/10/2019	Borehole cleaning completed after 2 hours of pumping
17/01/2020	Hydrogeological testing: step test at 0.135/0.2/0.28-0.3 l/s
20/01/2020 and 18/02/2020	Hydrogeological testing: constant rate test First test at 0.21 l/s ended early due to excessive drawdown Second test at 0.1 l/s ran for 5 hours

3.1 SENSORS INSTALLED

3.1.1 Hydrogeological data logger

A CT2X data logger was installed in GGA03r on 09/01/2020 to a depth of approximately 30 m below the top of the casing, and was raised on 13/01/2020 to approximately 20 m below the top of casing. The data logger was removed during the test pumping on GGA03r (Drilcorp installed their own data logger during the tests). The data logger was re-installed upon completion of the constant rate test on borehole GGA03r, approximately 20 m below the top of the casing, and

remained in place for the duration of the remaining test pumping of the surrounding UKGEOS boreholes. It was removed from the borehole after the completion of the test pumping programme, to allow the borehole casing to be cut down. The data logger was reinstalled in GGA03r on 16/03/2020 for continuous downhole groundwater monitoring. As with all groundwater observations in this borehole, the data logger is monitoring groundwater conditions only in the screened target interval, a sandstone below rockhead and above the Glasgow Upper mine working.

This data logger measures the following parameters:

- Pressure (mbars) (which is converted to borehole water level by compensating for air pressure, measured separately onsite by a barometer)
- Groundwater temperature (°C)
- Groundwater conductivity (specific electrical conductivity or SEC) (µS/cm) (also expressed as Salinity (PSU) and Total dissolved solids (mg/L))

Data from the logger will be downloaded monthly and become available on the UKGEOS website.

4 Borehole logs

4.1 DRILLERS' LOG

The drilling contractors log is included in the data pack [*Drillers_Log_GGA03r.pdf*]. This is a site record of the lithologies encountered, as recorded on-site by the drillers. Apart from the upper part of the made ground section which is based on trial pits, this log was not recorded by a geotechnical engineer. Due to the nature of the driller's log, there are differences between it and BGS rock chip log (Section 4.2).

The borehole information summary sheets at the end of the driller's log records the drilling progress each day, casing sizes, flush type used etc. All eleven drillers' logs for UKGEOS boreholes at Cuningar Loop have been exported by the drilling contractor to the file *UKGEOSCuningar_BAA4203_FinalAGS.AGS* in the Association of Geotechnical Specialists standard text file format.

4.2 BGS ROCK CHIP LOG

BGS geologists were on site during borehole drilling to collect samples, record a field lithological log and to make decisions based on this log, such as the positioning of the borehole screens and seal. A one litre tub of rock chips from the open hole drilling was generally taken every metre, to be representative of the lithologies encountered in that metre. Other notable features such as the top and base depths of key intervals such as coals and mine workings were recorded in discussion with the drillers.

Subsequently the rock chip tubs were transported to BGS Edinburgh. Tubs containing unconsolidated superficial deposit tubs were placed in a cold store. Rock chip tubs were dried and logged by BGS geologists working in a laboratory with the aid of a microscope.

The resulting lithological log record [*Detailed_BGS_Rockchiplog_GGA03r.pdf and .xlsx*] gives the percentage of lithologies returned as rock chips within the 'metre' tub, with some sedimentological characteristics. The dictionaries controlling the majority of the fields are provided via the tab on the spreadsheet. A sedimentological scheme was used to describe the lithologies to facilitate comparison with core logging of UKGEOS borehole GGC01:

- The Udden-Wentworth grain size scale was used

- With initial logging taking place at drill site, a classification level of mud/mudstone, sand/sandstone was used. Following the hierarchy of the BGS Rock Classification Scheme (Hallsworth & Knox, 1999), subsequent logging in the laboratory subdivided mud/mudstone to clay and silt, and to the sandstone grain sizes (fine, medium etc) and the gravel to granule and pebble grades. Percentages on the graphic logs are given at the mud/mudstone and sand/sandstone classification level. Detail on clay/silt etc is given in the descriptive field in the BGS rock chip log.
- Grain sizes, angularity, sorting and percentages etc were referred from a standard grain size card based on Tucker (2011).
- Logging was not based on ISO 14688-1:2002 (geotechnical engineering standard)

5 Archived rock chip samples

Section 4.2 describes how representative one litre tubs of rock chips were taken every metre during open hole drilling. These samples have been archived in the National Geological Repository at BGS Keyworth for future research. The data pack includes a spreadsheet summarising the rock chip tubs available [*GGA03r_archived_rock_chips.xlsx*]. For the composition of the samples refer to the BGS rock chip log [*Detailed_BGS_Rockchiplog_GGA03r.pdf and .xlsx*].

During-drilling fluid and rock chip samples were also supplied to a number of University groups for their ongoing research. Data from that research will be returned to NERC/BGS data centre and made publically available on a 2 year timescale.

6 Initial hydrogeological indications

A brief summary is provided here of various hydrogeological measurements recorded during borehole construction, cleaning and test pumping. Further detail will be provided in future hydrogeological information releases.

6.1 BOREHOLE CLEANING

Borehole cleaning was undertaken after the installation of casing and slotted screen with the aim of removing any drilling-related material and fluid from inside the casing.

Borehole cleaning was done using an airlift pump and carried out for two hours, by which time the field parameters being monitored (Table 5) had stabilised. A summary of the borehole cleaning carried out is in Table 5.

Table 5 Overview of GGA03r borehole cleaning parameters

Technique used	***Airlift pump***
Date	*24/10/2019*
Length of time borehole cleaning continued (minutes)	*120*
Approximate volume of water removed (m^3)	*0.219*
Borehole water level drawdown (m)	*Not recorded*
Borehole volume (m^3)	*0.697*
Number of borehole volumes removed	*Approx. ⅓*
Field parameters measured for borehole cleaning monitoring	*Dissolved oxygen/ SEC (conductivity)/ Temperature/ Oxidation-reduction potential/ pH/ turbidity*
Average temperature of removed water (degrees C)	*11.8*
Summary of outcome	*At the end of cleaning the water quality field parameters were stable and the turbidity readings were consistently zero*

6.2 TEST PUMPING

Test pumping was carried out to establish the hydraulic characteristics of the mine workings, shallow bedrock and superficial deposits, and the extent to which these units are connected at individual sites and across different sites. The first consistent set of groundwater samples for chemistry analysis was also collected during test pumping.

Two tests were carried out. A step test was carried out first to establish yield-drawdown relationships in the borehole, allow selection of an appropriate pumping rate for a constant rate test, and allow estimations of borehole efficiency. After groundwater level recovery, a constant rate test at a suitable rate to allow estimation of aquifer transmissivity and other hydraulic parameters was completed.

Each test was carried out using a submersible pump of suitable capacity to provide the desired pumping rate(s). During each test, groundwater levels in the tested borehole were monitored using a downhole pressure transducer, and also by manual dips. Groundwater levels in all other boreholes on site were monitored throughout the test using a downhole pressure transducer, and by occasional manual dips.

The first constant rate test carried out on GGA03r on 20th January 2020 was ended before water levels stabilised, because water level drawdown in the borehole was too large, even at the lowest rate possible by the pump used, and fell to the level of the pump. A second constant rate test was carried out on 18th February 2020 at a lower flow rate using a smaller pump, for the planned five hours.

Initial hydrogeological indications from the test pumping indicate that borehole GGA03r is low yielding. Detailed test pumping data and interpretations will be given in a future hydrogeological data release.

Table 6 Overview of GGA03r test pumping

Step test	
Date of step test	*17/01/2020*
Number of steps	*3*
Length of steps (hours)	*1 to 1.5*
Length of pumping during step test (hours)	*4*
Length of manually monitored recovery during step test (hours)	*1*
Pumping rates for each step (l/s)	*0.135/0.2/0.28-0.3*
Maximum drawdown at end of final step (m)	*30.16*
Constant rate test 1	
Date of constant rate test	*20/01/2020*
Length of pumping during constant rate test (hours)	*Approx. 4 (however, pump stopped for 25 minutes during the test)*
Length of manually monitored recovery during constant rate test (hours)	*1*
Pumping rate for constant rate test (l/s)	*0.21*
Maximum drawdown at end of constant rate test (m)	*28.65*
Average groundwater temperature during constant rate test (degrees C)	*12.3*
Groundwater geochemical samples collected during constant rate test	*One sample set: after approx. 2 hours*
Constant rate test 2	
Date of constant rate test	*18/02/2020*
Length of pumping during constant rate test (hours)	*5*
Length of manually monitored recovery during constant rate test (hours)	*1*
Pumping rate for constant rate test (l/s)	*0.1*
Maximum drawdown at end of constant rate test (m)	*8.42*
Average groundwater temperature during constant rate test (degrees C)	*11.6*
Groundwater geochemical samples collected during constant rate test	*None taken*

7 Initial geological interpretation

Integration of drillers' information, rock chip logs, preliminary hydrogeological indications from borehole cleaning and test pumping, together with correlation to legacy borehole data has allowed an initial geological interpretation of borehole GGA03r (Figure 1).

The made ground composition including brickwork, wood, glass etc is as expected from legacy data nearby and the prior land use history as a site where housing demolition rubble was disposed of. The thickness of the made ground at 8.3 m drilled depth was less than pre-drill prognosis

(Appendix B), though compatible with a complex and variable anthropogenic deposit and boreholes GGA01 and GGA02 nearby.

The superficial deposits are interpreted as a Quaternary age succession of glacial and post-glacial deposits, following existing legacy interpretations and geological models (e.g. Arkley, 2019). A preliminary interpretation comprises sand, gravel, silt and clay of the alluvial Gourock Sand Member passing downwards to the raised marine Paisley Clay Member at around 15 m drilled depth (Figure 1). Interpretation of the remainder of the superficial deposit succession was not possible due to losses in drilling returns (Figure 1). Rockhead was recognised at 27.4 m drilled depth, within error limits of pre-drill prognosis (Appendix B).

The bedrock succession appears typical of this part of the Scottish Middle Coal Measures Formation above the Glasgow Upper coal with fine- to medium-grained sandstone units, a thin coal and more dominant units of claystone and siltstone than recorded in GGA01 and GGA02 nearby. The target, screened interval is a fine- to medium-grained sandstone with trace siltstone, claystone and coal (Figure 1) around 8 m above the Glasgow Upper Coal mine working.

8 References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: https://envirolib.apps.nerc.ac.uk/olibcgi.

Datasets are available at https://www.ukgeos.ac.uk/data-downloads

ARKLEY, S. 2018. Model metadata report for the Glasgow Geothermal Energy Research Field Site superficial deposits model. *British Geological Survey Open Report*, Nottingham, UK, OR/18/064, 50pp. http://nora.nerc.ac.uk/id/eprint/524556/

BURKIN, J, and KEARSEY, T. 2019. Model metadata report for Glasgow Geothermal Energy Research Field Site bedrock model. *British Geological Survey Open Repor*t Nottingham, UK, OR/18/053, 18pp. http://nora.nerc.ac.uk/id/eprint/522737/

HALLSWORTH, C R, and KNOX, R W O'B. 1999. BGS Rock Classification Scheme Volume 3. Classification of sediments and sedimentary rocks. *British Geological Survey Research Report*, RR 99-03.

KEARSEY, T, GILLESPIE, M, ENTWISLE, D, DAMASCHKE, M, WYLDE, S, FELLGETT, M, KINGDON, A, BURKIN, J, STARCHER, V, SHORTER, K, BARRON, H, ELSOME, J, BARNETT, M, and MONAGHAN, A. 2019. UK Geoenergy Observatories Glasgow: GGC01 cored, seismic monitoring borehole – intermediate data release. *British Geological Survey Open Report*, OR/19/049, Nottingham, UK, 36pp. http://nora.nerc.ac.uk/id/eprint/525009/

MONAGHAN, A A, Ó DOCHARTAIGH, B E, FORDYCE, F M, LOVELESS, S, ENTWISLE, D, QUINN, M, SMITH, K, ELLEN, R, ARKLEY, S, KEARSEY, T, CAMPBELL, S D G, FELLGETT, M, and MOSCA, I. 2017. UKGEOS: Glasgow Geothermal Energy Research Field Site (GGERFS): initial summary of the geological platform. Nottingham, UK, *British Geological Survey Open Report*, OR/17/006. http://nora.nerc.ac.uk/id/eprint/518636/

MONAGHAN, A A, STARCHER, V, Ó DOCHARTAIGH, B E, SHORTER, K M, and BURKIN, J. 2019. UK Geoenergy Observatories : Glasgow Geothermal Energy Research Field Site: Science Infrastructure Version 2. Nottingham, UK, *British Geological Survey Open Report*, OR/19/032 http://nora.nerc.ac.uk/id/eprint/522814/

TUCKER, M. E.. 2011, Sedimentary Rocks in the Field: A Practical Guide (Geological Field Guide) 4th edition, Wiley-Blackwell 288pp

Appendix A: Summary of borehole GGA03r files in this information release

Table **7** Summary of files in the borehole GGA03r information release

Description	File name	File type
BAM Drillers log – an engineering format log with lithological information as recorded on drill site by the drilling contractor (not a geotechnical engineer). *NOTE: depths are given relative to drill platform level*	Drillers_Log_GGA03r.pdf UKGEOSCuningar_BAA4203_FinalAGS.AGS *(this covers all 11 UKGEOS boreholes at Cuningar Loop)*	PDF AGS format
BGS log- detailed. A log recording the percentage of different lithologies returned as rock chips during the open hole drilling on a metre by metre basis. Included as a spreadsheet and a visualisation plot. *NOTE: depths are given relative to drill platform level*	Detailed_BGS_Rockchiplog_GGA03r.pdf Detailed_BGS_Rockchiplog_GGA03r.xlsx	XLSX, PDF
BGS summary log – a 1 or 2 page visualisation of the BGS log and summary interpretation. *NOTE: depths are given relative to drill platform level*	Summary_BGS_Log_GGA03r.pdf	PDF
Spreadsheet of archived rock chip samples *NOTE: depths are given relative to drill platform level*	GGA03r_archived_rock_chips.xlsx	XLSX

Appendix B Pre-drill borehole prognosis

The pre-drill borehole prognosis (Figure 5) was produced from semi-regional superficial deposits, bedrock and mine 3D geological models (Arkley, 2019; Burkin and Kearsey, 2019) and legacy boreholes nearby. The prognoses were used in planning the depth, spacing and design of the boreholes and were indicative of the likely unit depths to be encountered. As the prognoses were not based on detailed site specific interpretations, the uncertainty and error values were understood to be quite large.

The pre-drill borehole prognoses as shown in Figure 5 were updated on paper at site during the drilling phase. Being the pre-drill information, Figure 5 does not represent the learnings or local, site specific considerations used during the drilling phase.

British Geological Survey: UKGEOS Project

GGERFS Prognosed Stratigraphy

Image not for engineering use

GGERFS01 | GL = +11 m Ordnance Datum

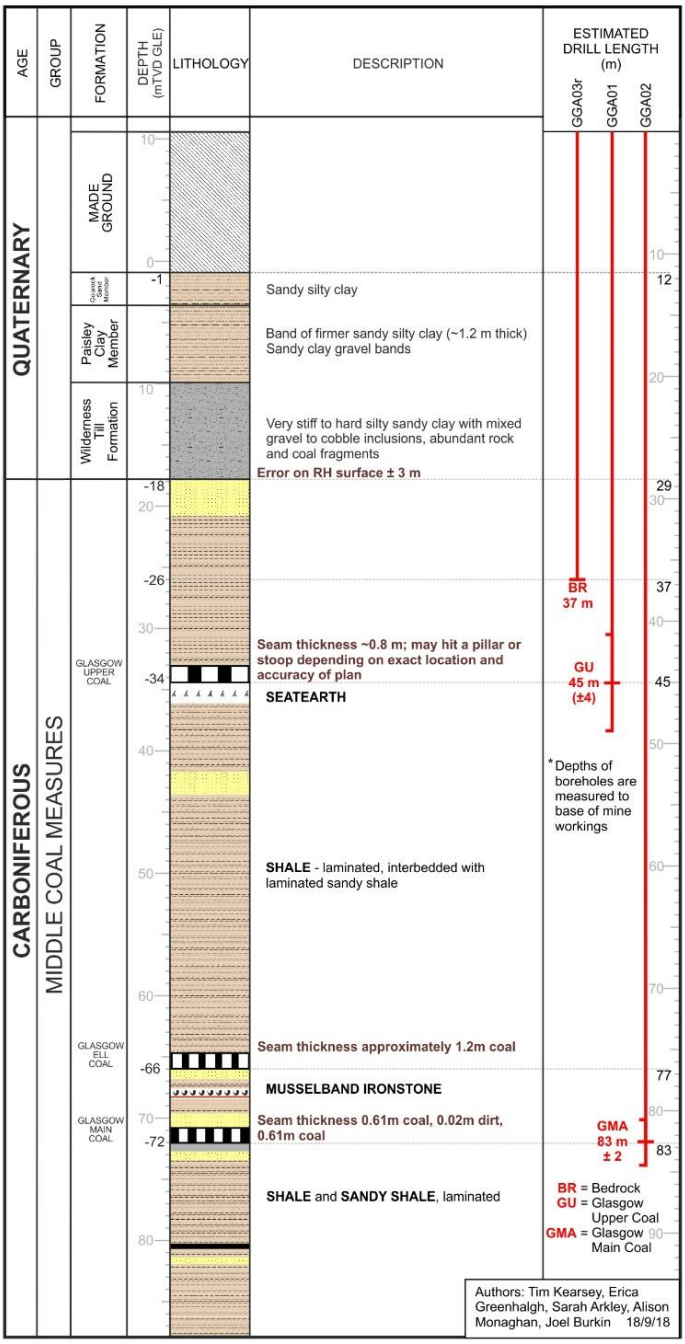

Figure 5 Pre-drill borehole stratigraphic prognosis for site GGERFS01, boreholes GGA01, GGA02, GGA03r based on semi-regional geological models and nearby legacy boreholes