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Environmental baseline characterisation and monitoring borehole GGA06r, UK Geoenergy Observatory, Glasgow

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OPEN REPORT OR/20/026

Environmental baseline characterisation and monitoring borehole GGA06r, UK Geoenergy Observatory, Glasgow

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Front cover

uPVC casing as used in borehole GGA06r and pre-glued gravel pack over screened section (left)

Bibliographical reference

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Summary

This report and accompanying data release describe the 'as-built' borehole GGA06r at the UK Geoenergy Observatory in Glasgow, as well as summarising hydrogeological testing and an initial geological interpretation.

Environmental baseline characterisation and monitoring borehole GGA06r at the UK Geoenergy Observatory in Glasgow is screened across a coarse sand and gravel in the superficial deposits. The borehole has proved to be low yielding on initial hydrogeological testing and has a hydrogeological data logger installed.

1 Introduction

Drilling of the environmental baseline and monitoring borehole GGA06r at Cuningar Loop in Rutherglen, Glasgow City Region, took place between 3rd July and 2nd August 2019 (start of drilling to casing installation date). The borehole targets a sand and gravel unit within the superficial deposits (Gourock Sand Member), with the slotted screen at +0.33 to -1.66 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_GGA06r.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/ccb1aabe-6062-4cb7-9731-535229316246 K Shorter, V Starcher, H F Barron, K Walker-Verkuil, A A Monaghan. 2020. UK Geoenergy Observatories Glasgow Borehole GGA06r 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 GGA06r, UK Geoenergy Observatory, Glasgow. British Geological Survey Open Report, OR/20/026.

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

Table 1 GGA06r as-built summary data

Borehole number	GGA06r	
Site	GGERFS02	
Easting (British National Grid)	262356.555	
Northing (British National Grid)	662681.402	
Drilling platform level (metres above Ordnance Datum AOD)	12.23	
Drilling started	03/07/2019	
Final casing installed	02/08/2019	
As-built borehole start height or datum (top Boode casing flange, metres AOD)	12.10	
Installation details		
Borehole detail	**Depths (drill length from drill platform level, metres)**	**Diameter size**
Made ground casing	0.0 – 11.4	8 ¾" (219.1 mm OD x 198.7 mm ID)
Boode Well (BW) plain casing	0.0 – 11.9	113.8 mm OD x 103.8 mm ID
BW Slotted pipe with pre-glued gravel pack	11.92 – 13.89	144 mm OD x 103.8 mm ID
Geological details	**Depths (drill length from drill platform level, metres)**	**Depths, relative to Ordnance Datum (m)**
Base of made ground	8.5	+3.73
Final drilled length	16.0	-1.66
BGS SOBI reference number	NS66SW BJ 3760	BGS ID 20693601

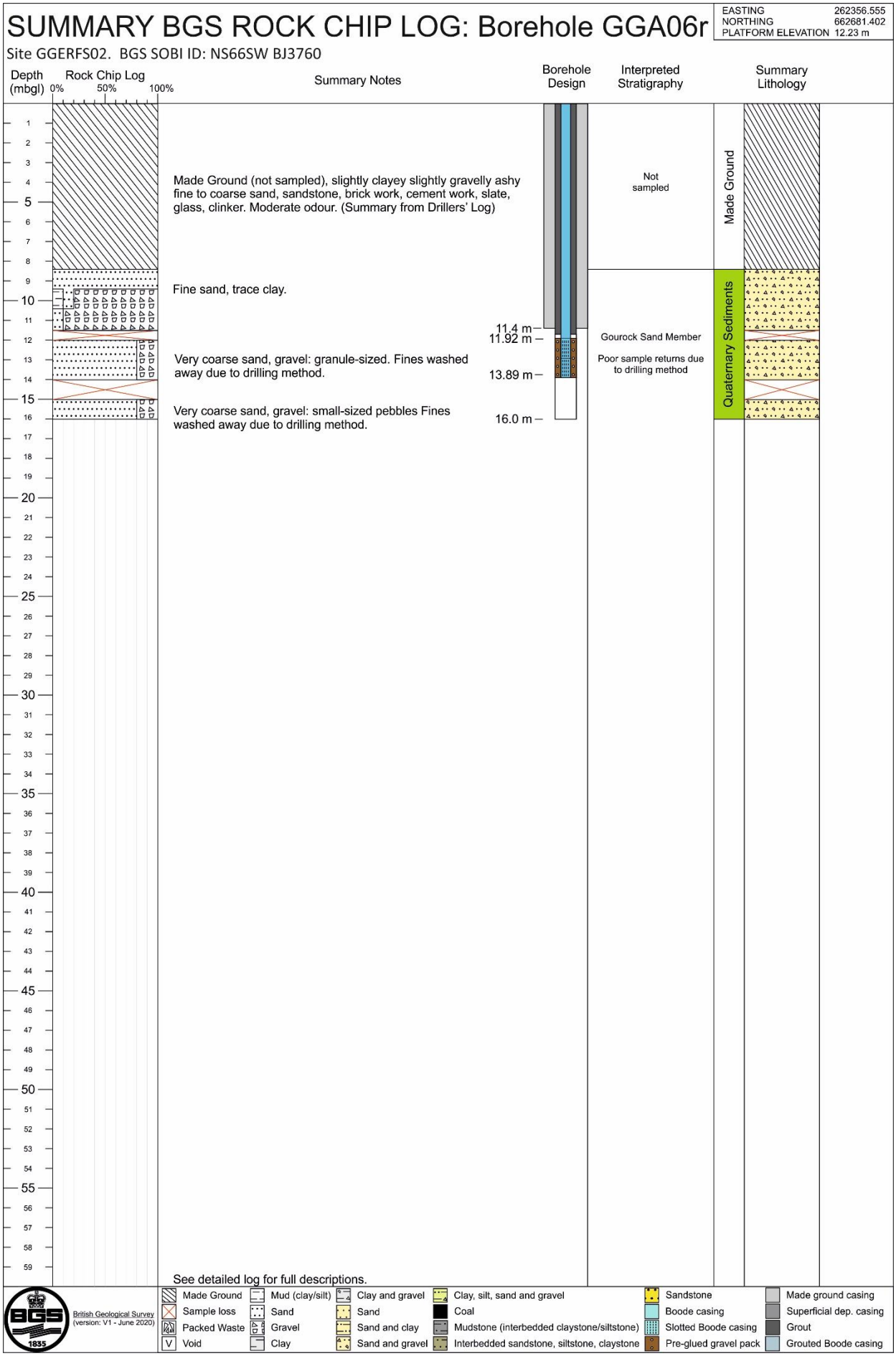

Figure 1 GGA06r summary log based on rock chip returns

1.2 AS-BUILT BOREHOLE LOCATION

Borehole GGA06r 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).

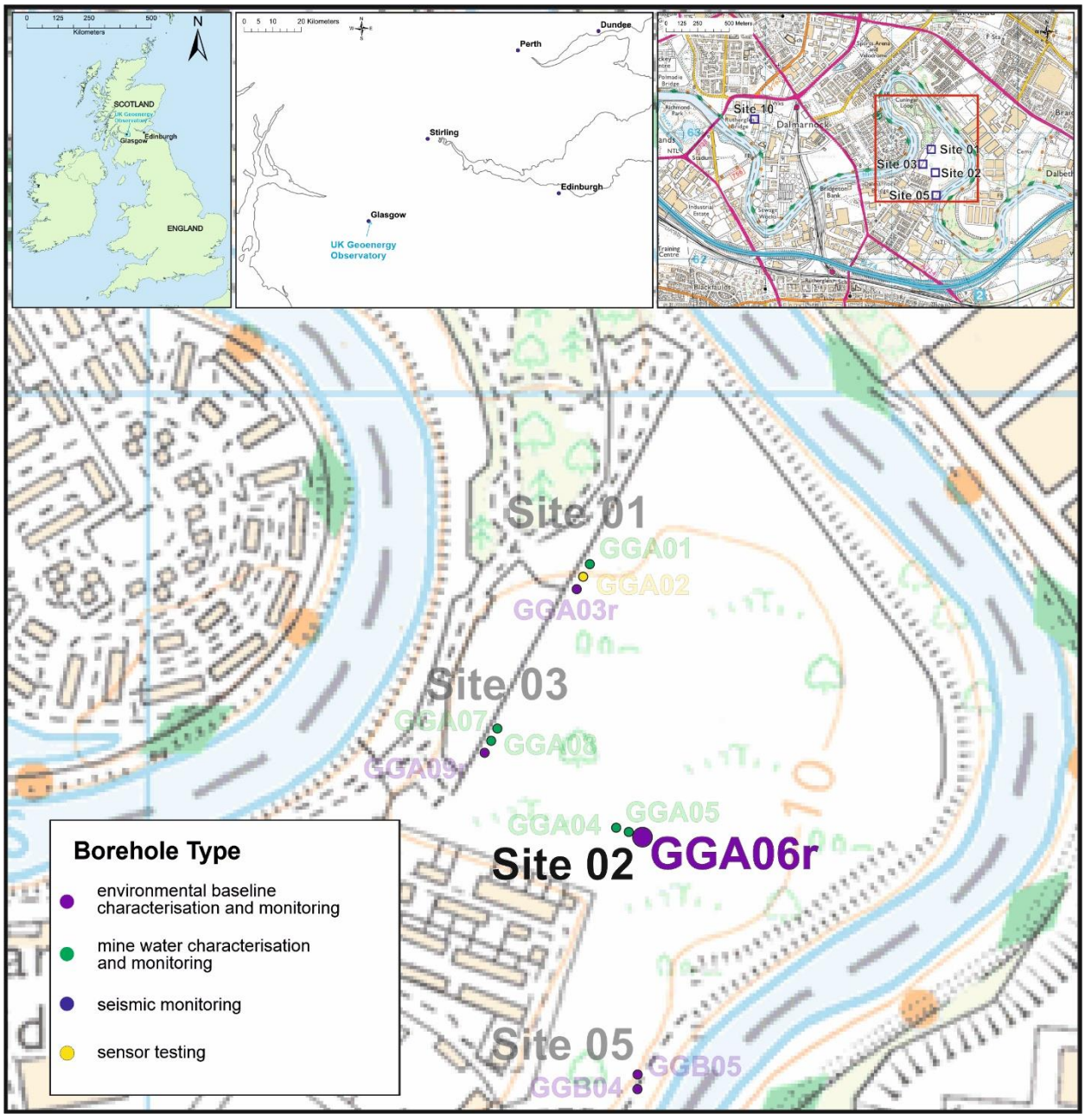

Figure 2 Location map of borehole GGA06r, UK Geoenergy Observatory in Glasgow. The other mine water and environmental baseline boreholes are shown for reference. Contains Ordnance Survey data © Crown copyright and database rights. All rights reserved [2020] Ordnance Survey [100021290 EUL].

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).

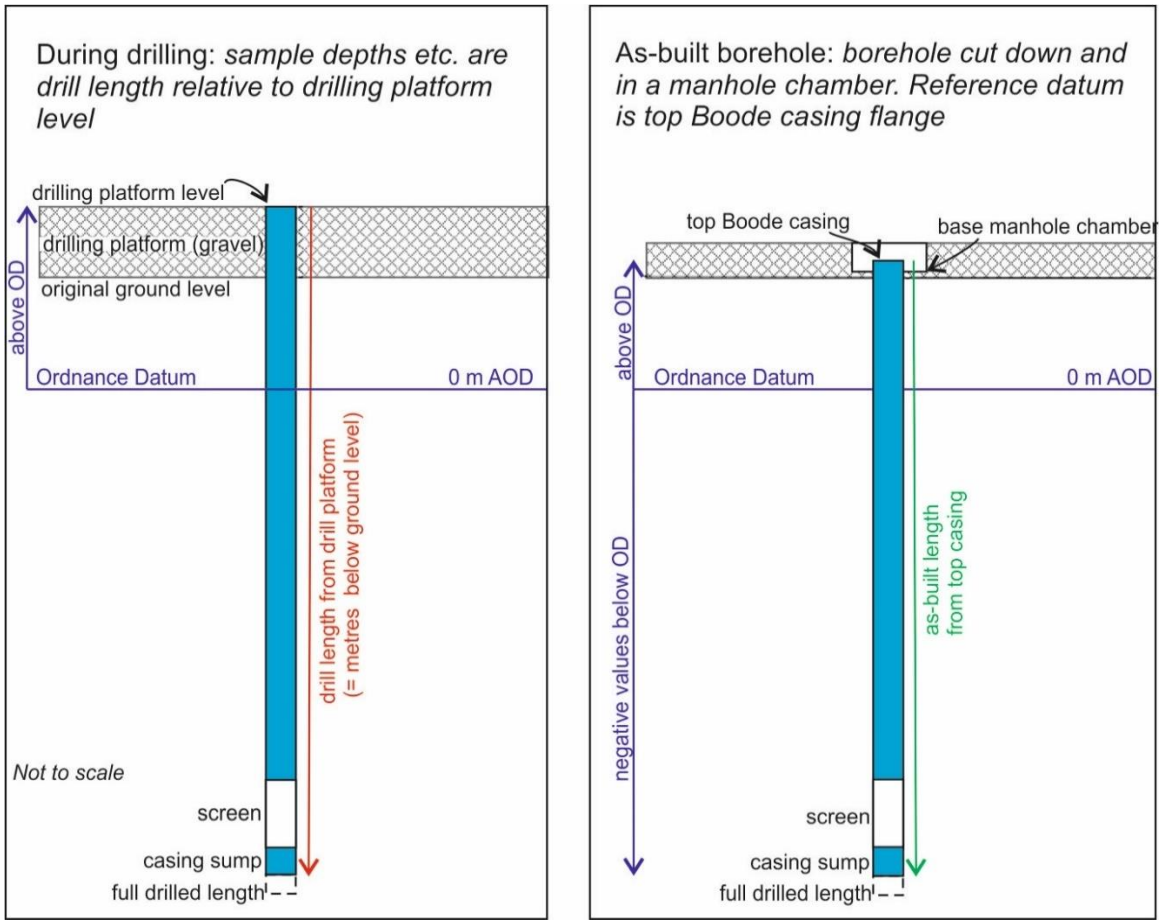

Figure 3 Images summarising the datums and depths/lengths/heights during drilling (left) and as-built (right)

Table 2 Summary of start heights and datums used for GGA06r

Stage	Borehole start height/ reference datum used (m AOD)	Used in
Drilling platform level – built up gravel platform	12.23	Drillers and BGS logs, sample depths
As-built borehole start height (top Boode casing flange)	12.10 m (recorded as 12.101)	Reference datum for future Observatory users
Conversion Rock chip sample depths, logs – to convert from drill length to beneath as-built borehole start height		As-built depth below start height = drill length – (12.23 – 12.10) m *i.e* As-built depth below start height = drill length – (0.13) m

2 As-built borehole design

The UK Geoenergy Observatory boreholes have been designed for a range of scientific research purposes over a 15-year lifetime. Their construction is not typical of mine water or environmental monitoring boreholes that would be installed for commercial schemes.

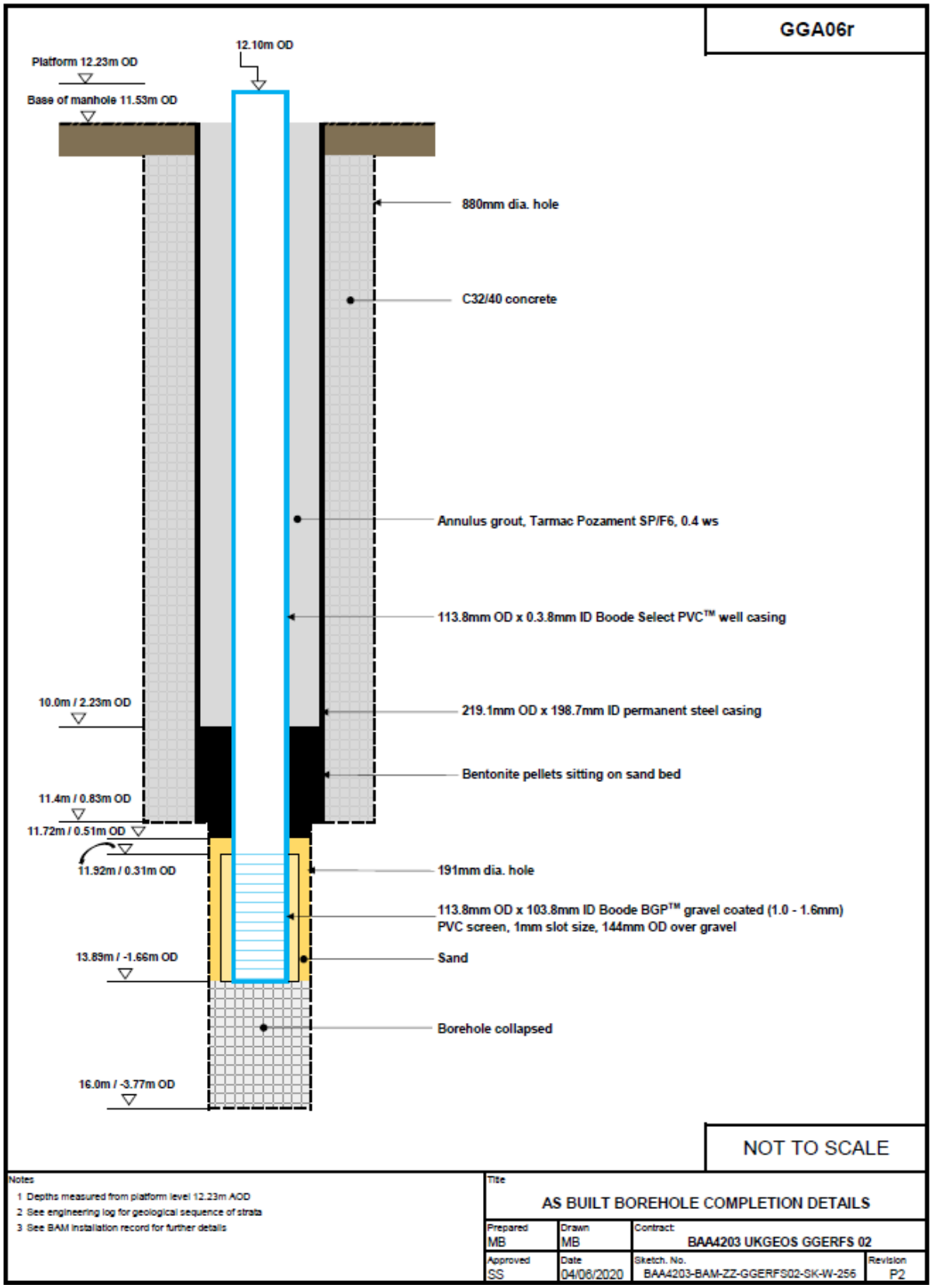

Figure 4 As-built borehole schematic for GGA06r

2.1 BASIS OF DESIGN

The basis of the GGA06r borehole design was as follows;

i. Separate borehole casings were installed through the made ground and 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 (a sand and gravel in the shallow superficial deposits) and is fully sealed above the screen, so that all hydrogeological observations from this borehole relate to this target interval.

iii. A screen slot size of 1 mm was used with a 1.0 to 1.6 mm sized bonded gravel pack attached.

iv. Sand filled the remaining annular space around the gravel pack and was overlain by a bentonite layer (10.00 – 11.72 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 GGA06r

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	11.92	+0.33	11.79
Base slotted screen	13.89	-1.66	13.76
Base installed casing sump	None	None	None

3 Drilling, casing, annulus grouting and testing methodology

Borehole GGA06r was drilled and cased in separate sections for made ground and superficial deposits. 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 (Table 4).

Table 4 summarises the steps involved in the drilling of GGA06r, 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
- 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.
- Fluid and rock chip samples were taken from the superficial deposits for academic researchers, and rock chip samples were taken for archiving in the BGS National Geological Repository.

- Shortly prior to drilling the target for this borehole, which had been a sand and gravel unit within the Paisley Clay Member (Appendix B) was changed to the shallower Gourock Sand Member. This was due to a change in the borehole drilling programme resulting in adjacent borehole GGA05 superficial section not being available first to guide the depth of the target sand and gravel interval within the clay-dominated formation.

Table 4 Summary of drilling, casing, grouting and testing of GGA06r. All depths are in metres below drilling platform level (mbgl).

Drilling and installation summary:	
03/07/2019	Drilled and installed made ground and superficial casing with BAM piling rig to 11.4 mbgl with a 34 ¾" (880 mm) auger – base made ground recorded at 8.5 mbgl
04/07/2019	Made ground and superficial casing grouted
02/08/2019	Drilled superficials to target screened interval depth with Beretta rig from 11.4 to 16.0 mbgl with a 7 ½" (191 mm) tri-cone bit. Installed casing Casing design: • Bentonite seal: 10.0 – 11.72 mbgl • Screened interval 11.92 – 13.89 mbgl, 1 mm slotted Boode casing with 1.0 to 1.6 mm bonded gravel pack • Sump: none **Problems encountered:** • The borehole was drilled to a depth of 16.0 mbgl and not 18.0 mbgl as originally planned due to mobile sand and gravel • No sump was possible due to borehole collapse back to 13.89 m on pulling out of hole • Returned samples collected were limited to due fast rate of penetration, drilling method and collection method
05/08/2019	Boode casing grouted and completed **Problems encountered:** • Sand was tagged at 1.5 m above bentonite plug in the borehole annulus, hole had further collapsed since completion of drilling. Annulus grouting was completed on top of the sand.
14/11/2019	Borehole cleaning
30/01/2020	Hydrogeological testing: Step pump test • Conducted at 0.1, 0.25, 0.45, 0.63 l/s (only 4 steps conducted due to capacity of pump)
31/01/2020	Hydrogeological testing: Constant rate pump test at 0.51 l/s

3.2 SENSORS INSTALLED

3.2.1 Hydrogeological data logger

A CT2X data logger was installed in GGA06r on 09/01/2020 to a depth of approximately 11 m below the top of the casing. The data logger was removed during the test pumping on GGA06r (Drilcorp installed their own data logger during the tests). The data logger was reinstalled upon completion of the constant rate test on borehole GGA06r, approximately 11 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 GGA06r on 16/03/2020 for the purpose of 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 sand in the superficial deposits.

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_GGA06r.pdf*]. This is a record of deposits 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 drillers' 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 borehole screens and seals. 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 deposits were placed in a cold store and logged by BGS geologists working in a laboratory with the aid of a microscope.

The resulting lithological log record [*Detailed_BGS_Rockchiplog_GGA06r.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, 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 [*GGA06r_archived_rock_chips.xlsx*]. For the composition of the samples refer to the BGS rock chip log [*Detailed_BGS_Rockchiplog_GGA06r.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 by initially pouring potable water into the borehole until there was a sufficient yield to use 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 GGA06r borehole cleaning parameters

Technique used	*Addition of potable water then airlift pump*
Date	*14/11/2019*
Length of time borehole cleaning continued (minutes)	*120*
Approximate volume of water removed (m^3)	*4.9*
Borehole water level drawdown (m)	*Not recorded*
Borehole volume (m^3)	*0.118*
Number of borehole volumes removed	*Approx. 42*
Field parameters measured for borehole cleaning monitoring	*Dissolved oxygen/ SEC (conductivity)/ Temperature/ Oxidation-reduction potential/ pH/ turbidity*
Average temperature of removed water (degrees C)	*4.7*
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 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.

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.

Initial hydrogeological indications from the test pumping indicate that borehole GGA06r is low yielding. Detailed test pumping data and interpretations will be given in a future hydrogeological data release.

Table 6 Overview of GGA06r test pumping parameters

Step test	
Date of step test	*30/01/2020*
Number of steps	*4*
Length of steps (hours)	*1*
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)	*0.12/0.26/0.4/0.62*
Maximum drawdown at end of final step (m)	*9.92*
Constant rate test	
Date of constant rate test	*31/01/2020*
Length of pumping during step test (hours)	*5*
Length of manually monitored recovery during step test (hours)	*1*
Pumping rate for constant rate test (l/s)	*0.52*
Maximum drawdown at end of constant rate test (m)	*9.64*
Average groundwater temperature during constant rate test (degrees C)	*11.8*
Groundwater geochemical samples collected during constant rate test	*Two samples: one after 2 hours and one after 4 hours*

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 GGA06r (Figure 1).

The made ground composition including brickwork, cement work, slate and glass 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 8.5 m drilled depth was less than pre-drill prognosis (Appendix C), though compatible with a complex and variable anthropogenic deposit and boreholes GGA04 and GGA05 nearby.

The superficial deposits of the target, screened interval are interpreted as Quaternary age, post-glacial deposits of the Gourock Sand Member, following existing legacy interpretations and geological models (e.g. Arkley, 2019). Though the drill returns were poor, the sand, gravel and trace of clay are correlated to deeper boreholes nearby.

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

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Appendix A Summary of borehole GGA06r files in this information release

Table 7 Summary of files in the borehole GGA06r 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_GGA06r.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_GGA06r.pdf Detailed_BGS_Rockchiplog_GGA06r.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_GGA06r.pdf	PDF
Spreadsheet of archived rock chip samples *NOTE: depths are given relative to drill platform level*	GGA06r_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.

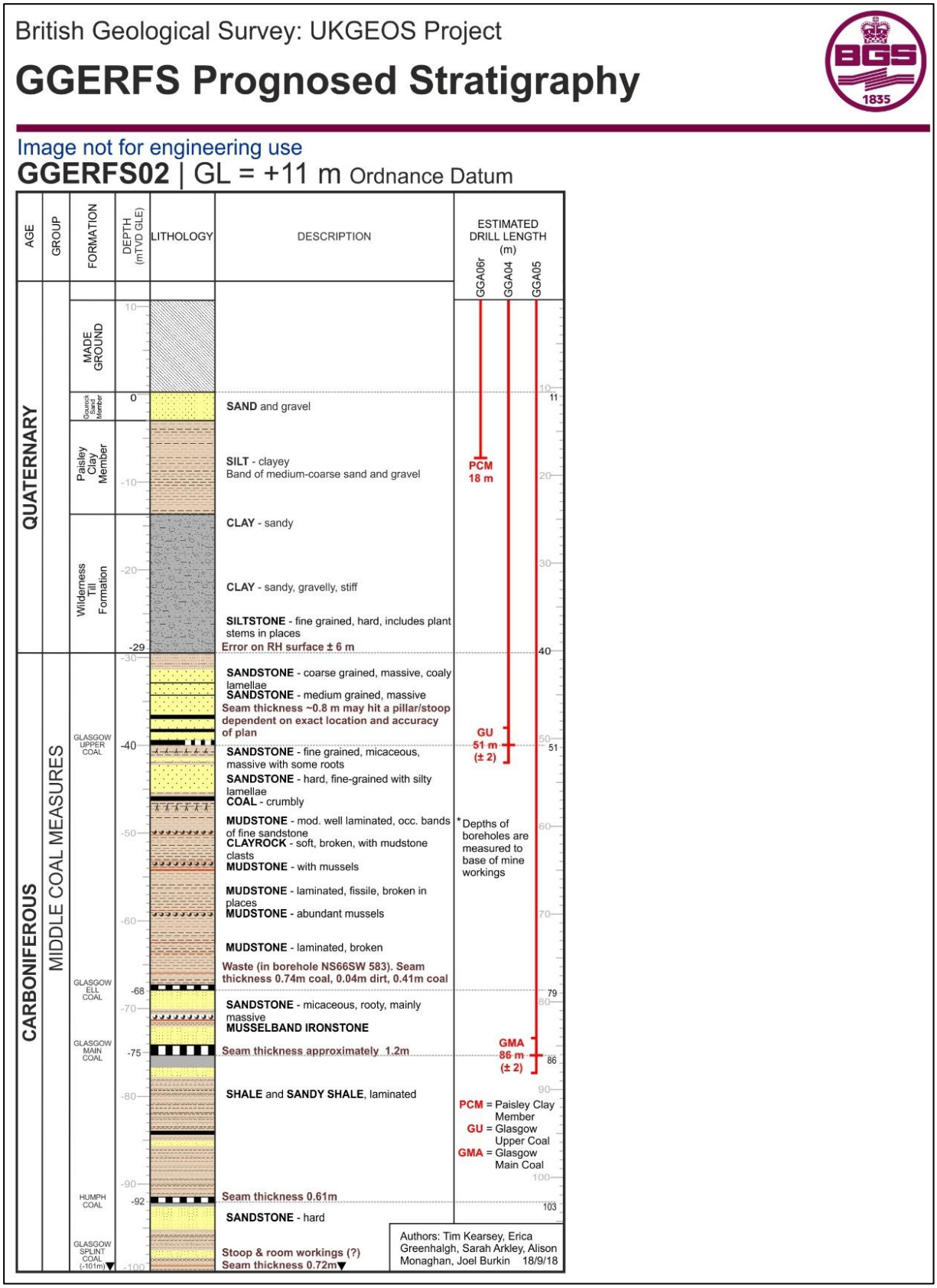

Figure 5 Pre-drill borehole prognosis for site GGERFS02, boreholes GGA04, GGA05, GGA06r based on semi-regional geological models and nearby legacy boreholes. Shortly prior to drilling the target for GGA06r borehole was changed to the shallower Gourock Sand Member due to change in drilling programme meaning GGA05 information on the depth of the target sand and gravel within the Paisley Clay Member was not available.