B CGL Site Investigation Report

Providing Ground Solutions

Elliott Wood Partnership Limited

Bicester Golf Club, Bicester, Oxfordshire

Geotechnical and Geoenvironmental Interpretative Report

March, 2022

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EXECUTIVE SUMMARY

Card Geotechnics Limited (CGL) has been commissioned by Great Wolf Resorts Limited (the Client), to undertake a ground investigation and to provide a Geotechnical and Geoenvironmental Interpretative Report for a site at Bicester Golf Club, Bicester, OX26 1TH. This report is issued in draft prior to formal issue following update and review.

The site is occupied by Bicester Golf Club, with the site being occupied by nine of the golf course holes incorporating fairways, putting greens, sand bunkers and mounds. A club house, hotel and spa with associated car parking area is situated in the southern part of the site. The proposed development for the site is understood to comprise the construction of a new hotel together with associated parking, water park, landscaping and infrastructure. The development history of the site does not show a significant risk of historical contamination.

Publicly available Unexploded Ordnance (UXO) mapping[1] has been consulted to review the risk posed by UXOs on the site. This mapping indicates that the site is present in a 'low' risk area.

The ground conditions encountered during the site investigation were found to comprise Topsoil overlying the weathered residual soils of the Cornbrash Formation, which in turn was underlain by limestone of the Cornbrash Formation to a maximum depth of ~3 m bgl. The Cornbrash Formation is underlain by the Forest Marble Formation which comprises of interbedded clay, mudstone, and limestone. Groundwater was encountered in four borehole locations during the investigation (BH02, BH03, BH04, and BH07) within the Cornbrash Formation and the Forest Marble Formation.

Based on the anticipated loadings of the proposed structure, shallow spread foundations (including strip/trench fill and/or pad foundations) are likely to be appropriate to support the proposed structure. An allowable bearing pressure of 300kN/m^2 is considered to be appropriate for foundations founded within limestones/marls of the Cornbrash Formation or cohesive deposits/mudstones/limestones of the Forest Marble Formation.

Shallow groundwater was encountered across the site during a monitoring visit at elevations ranging from 83.63 to 78.28 m AOD (depths of between 1.05mbgl and 2.31mbgl), with a deeper water horizon present at depths of between 4.3m and 4.72mbgl in the lower limestone (and indicated to be separated from the shallower groundwater by a bed of clay/mudstone). Groundwater is indicated to be flowing from the north to the south of the site.

[1] Zetica UXO. 2021. Risk Maps. Risk Maps | Zetica UXO [Accessed September 2021]

Based on the recorded water levels, dewatering and water control is likely to be required where foundations extend into/below the water table. Where foundations span two soil types, consideration should be given to reinforcement to mitigate differential settlement.

1. INTRODUCTION

Card Geotechnics Limited (CGL) has been commissioned by Great Wolf Resorts Limited (the Client), to undertake a Ground investigation for a site at Bicester Golf Club, Bicester, OX26 1TH.

This report presents the following:

- a summary of the Phase 1 desk-based ground conditions for the site and associated geotechnical and geoenvironmental risks based on this available published and unpublished data;
- details of the ground conditions encountered across the site during the main and supplementary investigations and results of the chemical and geotechnical laboratory testing;
- a source-pathway-receptor generic quantitative risk assessment based on the findings of the Phase 2 ground investigation works;
- geoenvironmental recommendations for addressing soil and groundwater contamination, ground gas and material management and re-use; and
- geotechnical recommendations for foundation design, roads/pavement design, basement construction & excavation, water control and sulphate protection for buried concrete.

The objectives of this report are to provide information to support a planning application for the proposed scheme and recommendations with respect to the ground conditions to assist in the development of the site.

2. SITE CONTEXT

2.1 Site Location

The site is located at Bicester Golf Club, Green Ln, Chesterton, Bicester OX26 1TH and lies approximately 3.5 km to the west of the town of Bicester. The National Grid Reference for the approximate centre of the site is 454976, 221632 and covers an area of approximately 21 hectares. A site location plan is included as Figure 1.

The site is bounded to the north by the A4095, to the west by the M40, and to the south by a 'B' road, with agricultural land beyond. To the east of the site is the village of Chesterton.

2.2 Site Description

A site walkover was undertaken on 18th October by CGL prior to site works. The walkover was completed ahead of the proposed site works to identify access constraints, agree exploratory hole locations, and discuss the use of water points across the site.

The following descriptions are based on observations made during the walkover survey, combining data from the Topographic Survey (1st Horizon Surveying & Engineering Limited drawing reference CS-GW5389), and remote sensing imagery obtained from online sources.

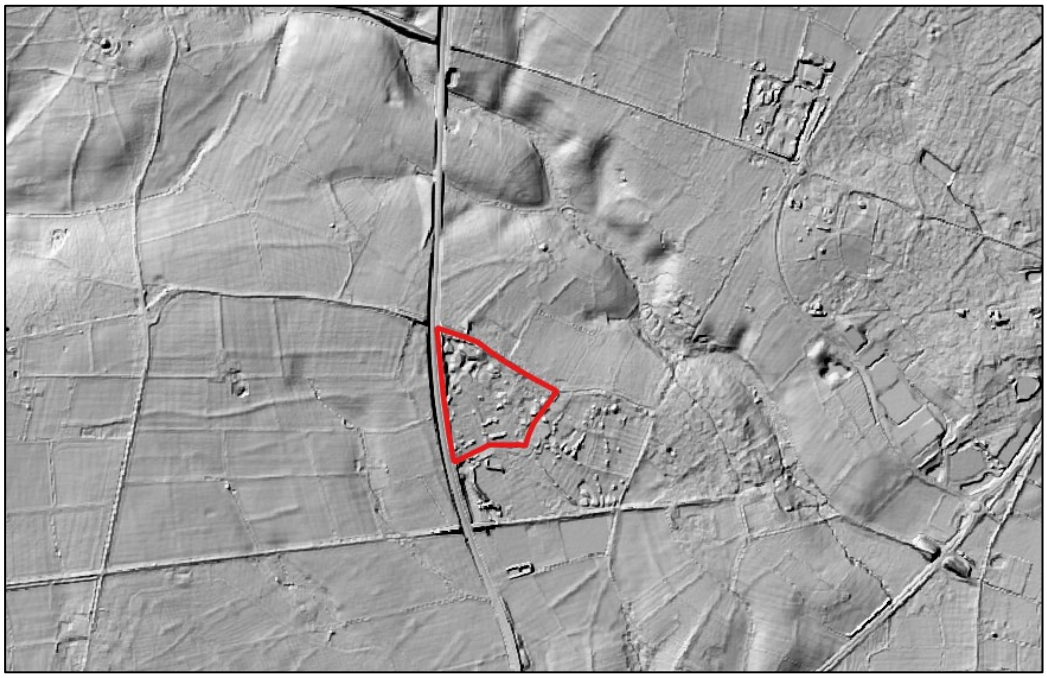
The weather during the visit was predominantly dry. In the period prior to the site visit the weather had been predominantly dry, with occasional periods of inclement rainfall.

The site is roughly triangular in shape with an area of approximately 19.8ha. Information obtained from a topographical survey and LiDAR imagery for the site indicates that the site slopes gently down towards the southeast from an elevation of approximately 88mOD in the north-western corner down to 75mOD in the south-eastern part of the site. Regionally, the site is situated within a generally gently sloping area that slopes down towards a valley some 600m to the east. An image showing the regional topography of the site is shown below in Plate 1.

The site is occupied by Bicester Golf Club, with the site being occupied by nine of the golf course holes incorporating fairways, putting greens, sand bunkers and mounds. Gravel surface pathways are locally present across the course, connecting fairways and greens.

Mature trees are present around the site margins and throughout the site (typically within rows between greens/fairways), together with landscaped areas and small wooded areas. Within the western margins of the site and central-northern areas are small woodland areas that include mature and semi-mature trees.

Plate 1. Regional LiDAR Imagery



Six ponds are situated in the north-west corner of the site, which are surrounded by mature trees and rough grass, with two ponds present in the eastern part of the site. The water level in the ponds varied, but was observed to be generally shallow at ~1m to ~2m deep. Several drainage ditches run across the golf course (with a 'main' drainage ditch running from northwest to southeast).

A club house, hotel and spa with associated car parking area is situated in the southern part of the site.

Site photographs are included as Figure 2.

2.3 Proposed Development

The proposed development for the site is understood to comprise the construction of a new hotel together with associated parking, water park, landscaping and infrastructure. Outline proposed development plans are included as Appendix A.

2.4 Previous Desk Study Information

A Geology and Water desk study and Flood Risk Assessment[2] has previously been completed for the site to assess ground conditions and groundwater levels at the site and wider area. A combination of BGS borehole data and Unmanned Aerial Vehicle (UAV) survey data was used to develop contour plots of water levels across the site, indicating groundwater contour levels of between 84.77mOD to 77.26mOD, with water generally flowing towards the south/south-west. The UAV survey is indicated to have been used to record the surface levels of several ponds down the slope. The study assumes that

[2] Curtins Consulting Ltd. 2019. *Great Wolf Lodge, Flood Risk Assessment*. Curtins Ref: 068535-CUR-00-XX-RP-C-00001.

groundwater level is continuous down the slope between the ponds. The findings of the previous study suggests that the ponds are fed by groundwater and are not lined.

2.5 Site History

The historical development of the site has been traced from Ordnance Survey maps dating between 1875 and 2021 provided by Groundsure. The maps were produced on scales ranging from 1:500 to 1:10,560 and are presented in Appendix B. Details of the site history summarised in Table 1 below.

Table 1. Summary of Onsite and Offsite Development

Historical Feature	*Area of Site*	*First Date Mapped*	*Last Date Mapped*	*Comments*
Onsite				
Agricultural fields	Entire site	1875	1966	The north-west corner of the site remains agricultural land until the 1999 aerial photo, after which time it becomes part of the golf course.
Golf course and club house	Entire site	1981	2021	
Lakes/ponds	North-west corner	2006	2021	
Quarry	Central-north	1923	1966	
Offsite				
Farm buildings and access track	Eastern boundary of site	1970	2021	Vicarage Farm
Springs	500 m to the south-west	1875	2010	On the 2021 map edition the pond is no longer shown, but a farm named 'Spring Well Farm' remains
Bignell Park	North of site boundary to >1000m	1875	2021	Large estate associated with Bignell House.

Since the earliest available historic maps the site has hosted open fields in the north and the estate associated with Bignell House.

With reference to freely available historical online maps[3], the site is mapped as open agricultural fields from the earliest available map edition of 1875 until 1966. Information from online sources indicate that the golf club was first constructed in 1973.

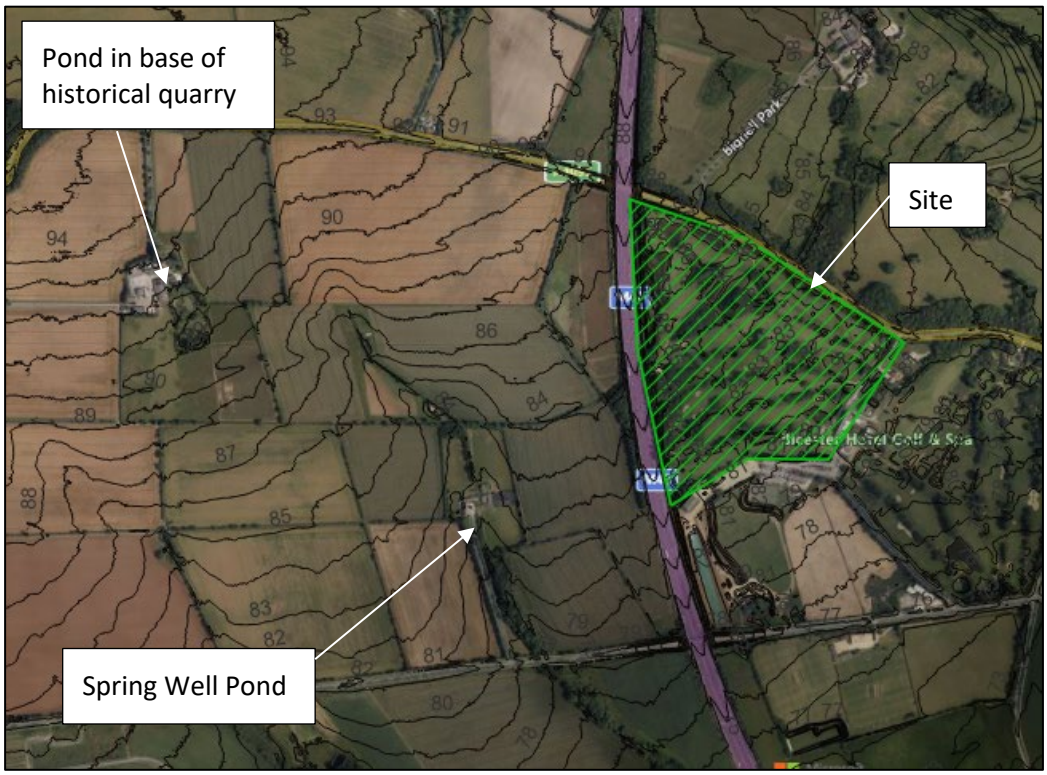
Historical mapping up until 1966 shows no ponds to have been present on site and, therefore, the existing ponds on-site are considered to have been constructed been constructed as part of the current golf club development. A historical aerial image dated 1999, as included in Appendix C, shows an area in the northern part of the site to have been undeveloped, with no ponds present.

Historical mapping also shows a 'Spring Well Pond' to the south-west of the site, at an approximate elevation of 82.3mOD. Other springs and ponds are shown at around this level in historical mapping. A

[3] National Library of Scotland. 2021. *Map Images.* Side by side georeferenced maps viewer - Map images - National Library of Scotland (nls.uk) [Accessed November 2021]

'Well' is shown to the north of the site in 1884 at an elevation of approximately 91.4mOD, however the depth of the well is not recorded. A pond is also shown to the west of the site at the base of a quarry excavated from the 91.4mOD contour line, however the depth of the quarry is not recorded. These features are visible on current aerial mapping.

Plate 2. Indicative Locations of Historical Mapped Springs and Quarries/Ponds



2.6 Unexploded Ordnance (UXO)

Publicly available Unexploded Ordnance (UXO) Mapping[4] has been reviewed to assess the risk of UXOs on the site. This mapping indicates that the site is in a 'low' risk area.

2.7 Ground Conditions

2.7.1 Published Geology

With reference to the British Geological Survey (BGS) Geoindex Website[5] and published geological map reference 219 (Buckingham)[6], the site is predominantly underlain by solid strata of the Cornbrash Formation, described by the BGS as typically comprising bluish grey to yellow brown fine to medium

[4] Zetica UXO. 2021. Risk Maps. https://zeticauxo.com/downloads-and-resources/risk-maps/ [Accessed 09/11/2021].
[5] British Geological Survey (BGS). 2021. *Geoindex Onshore.* GeoIndex - British Geological Survey (bgs.ac.uk) [Accessed 22/11/2021].
[6] BGS (2002). Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series. Sheet 219, Buckingham

grained limestone with occasional partings of calcareous mudstone[7]. In the north-eastern and western part of the site, solid strata of the Forest Marble Formation are indicated to outcrop at surface. The Forest Marble Formation is described by the BGS as typically comprising greenish-grey silicate mudstone interbedded with limestone[8].

Superficial formations are not recorded on the BGS mapping for the site area. However, given the anticipated presence of limestone bedrock beneath the site area and the periglacial (permafrost) climatic legacy a ground profile of brecciated bedrock may be encountered.

Infilled Ground – (Artificial Deposit) are shown to the immediate northeast of the site, beyond the A4095, as identified in the Geological Disclosure Report included in Appendix C.

2.7.2 BGS Borehole Records

A number of historical BGS boreholes are shown in the vicinity of the site, as shown within the Geological Disclosure Report included in Appendix D. A review of the BGS borehole data was carried out as part of a previous desk study carried out for the site, a summary of which is included as Appendix B.

2.8 Radon

With reference to the Environmental Disclosure Report, the site is located within an aera where up to between 1% and 3% of properties are above the Action Level. Therefore, radon protective measures are not required for the site.

2.9 Mining

Three records of surface ground workings are shown on-site within the Geological Disclosure report in Appendix C, noted between 1923 and 1966.A record of a historical limestone quarry is recorded on-site, as shown on historical maps to have been present within the north-eastern part of the site. Further quarries are shown approximately 113m to the north-east, associated with limestone quarrying.

2.10 Natural Cavities

With reference to the Geological Disclosure Report included in Appendix C, records of natural cavities are not recorded within 500m of the site.

[7] British Geological Survey (BGS). 2021. *The BGS Lexicon of Named Rock Units – Cornbrash Formation.* BGS Lexicon of Named Rock Units - Result Details [Accessed 22/11/2021].
[8] British Geological Survey (BGS). 2021. *The BGS Lexicon of Named Rock Units – Forest Marble Formation.* BGS Lexicon of Named Rock Units - Result Details [Accessed 22/11/2021].

2.11 Hydrogeology and Hydrology

The Environment Agency (EA) has produced an aquifer designation system consistent with the requirements of the Water Framework Directive. The designations have been set for superficial and solid geologies and are based on the importance of aquifers for potable water supply and their role in supporting surface water bodies and wetland ecosystems.

The solid geology of the Cornbrash Formation is classified as a Secondary A Aquifer.

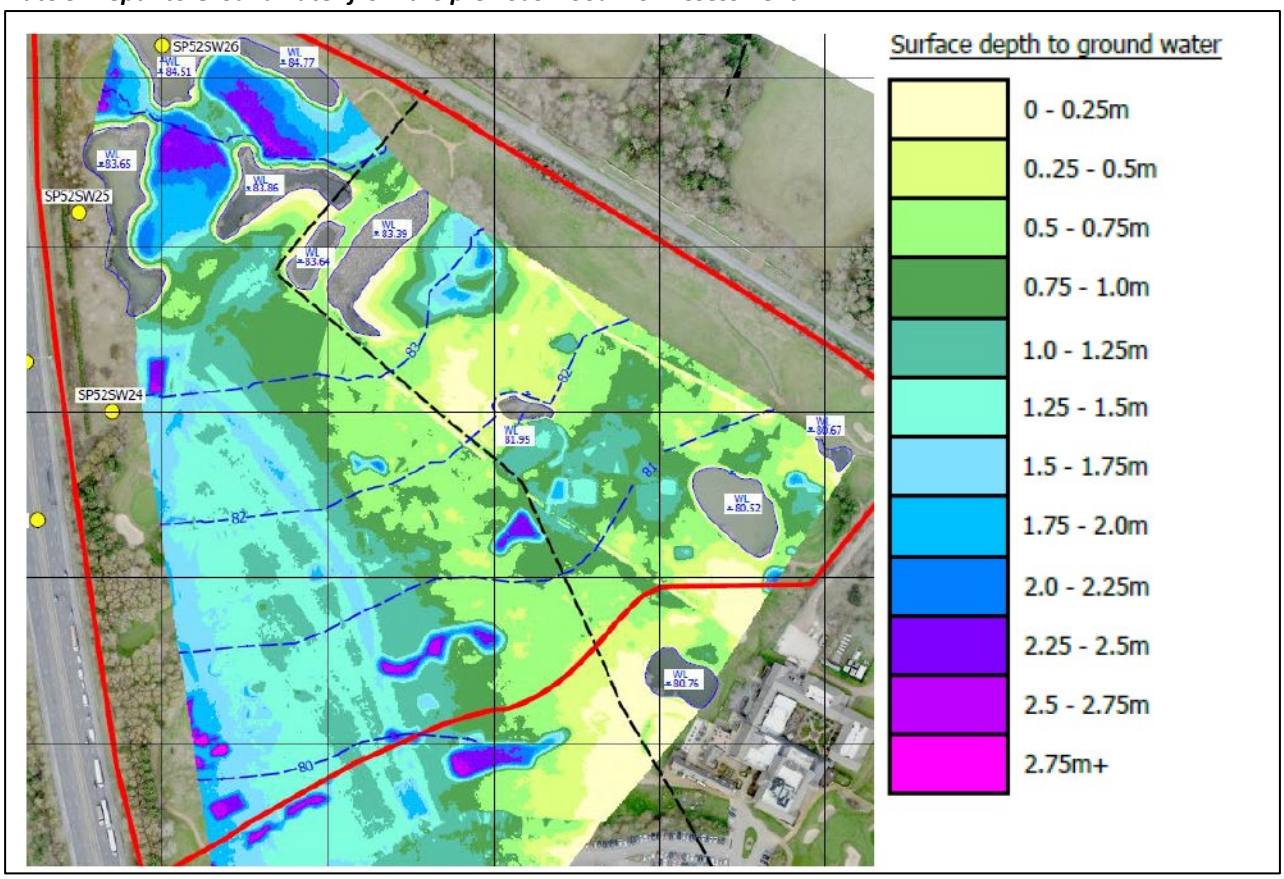
In October 2019, a Flood Risk Assessment[9] was carried out at the site, the findings of which are summarised below.

- The topography of the site was found to generally slope from north-west to south-east, with levels dropping from 87 m AOD to 81 m AOD. There are several landscaping features across the site associated with the golf course, including ponds and lakes, the majority of which are concentrated in the north of the site. These ponds are believed to be groundwater fed.
- The closest surface water feature is the Gagle Brook 500 m to the north-east of the site which flows from north to south and joins the River Ray approximately 4 km downstream. Thames Water reported that there are no public sewers or surface water sewers in the vicinity of the site
- The site was found to be underlain at rockhead by the Cornbrash Formation (limestone and mudstone) which is underlain by the Forest Marble Formation which is in turn underlain by the White Limestone Formation at depth, all of which form part of the Great Oolite Group.
- The Cornbrash formation is a local unconfined aquifer and is categorised by the Environment Agency (EA) as a Secondary A Aquifer The groundwater in the Cornbrash Formation is perched on the low permeability Forest Marble Formation beneath which acts as an aquiclude and separates the Cornbrash Formation from the White Limestone Formation beneath.
- According to the EA Flood Map for Planning the site is in Flood Zone 1, which means it has a low (1 in 1000 year) probability of flooding from rivers. The risk of surface water flooding is also considered to be low.

[9] Curtins Consulting Ltd. 2019. *Great Wolf Lodge, Flood Risk Assessment*. Curtins Ref: 068535-CUR-00-XX-RP-C-00001.

- The site is classified as greenfield but is not completely undeveloped, as it benefits from some formalised drainage networks – ditches across the site, which were likely installed in the 1980s for land drainage for the golf course.

***Plate 3. Depth to Groundwater from the previous Flood Risk Assessment*[10]**



2.12 Environmental Disclosures

The Environmental Disclosure Report was obtained to provide information on the environmental setting of the site and assist in identifying possible sources of ground contamination. A summary of the pertinent points is set out below. A copy of the report is included in Appendix C.

- Two Historical industrial land uses are recorded on-site associated with unspecified quarries. No further historical industrial land uses are shown within 250m of the site.
- Five historical tanks are shown within 250m of the site, the closest being 27m to the northeast dated 1995.
- No historical energy features are recorded within 250m of the site.

[10] Curtins Consulting Ltd. 2019. *Great Wolf Lodge, Flood Risk Assessment*. Curtins Ref: 068535-CUR-00-XX-RP-C-00001.

- No historical garages or petrol stations are recorded within 250m of the site.
- No historical or active licensed waste sites or landfill sites are located within 250 m of the site.
- There are no records of sites determined as contaminated land, COMAH sites, sites associated with IPC activities, sites associated with Part A(1) or Part A(2) or (B) activities, or radioactive sites within 250m of the site.
- There are no recorded pollution incidents recorded within 250m of the site.
- The site is located within an area where up to between 1% and 3% are above the Action Level. Therefore, radon protective measures are not required for the site.

3. PRELIMINARY RISK ASSESSMENT

3.1 Introduction

Historical contamination of land may present harm to human health and the environment. Current UK legislation stipulates that the risk associated with potential land contamination is assessed and remediated, if necessary. Under the Town and Country Planning Act 1990 (as amended), potential land contamination is a "material planning consideration" together with the National Planning Policy Framework (revised February 2019), which means that a planning authority must consider contamination when they prepare development plans or consider individual applications for planning permission. It is the responsibility of the developer to carry out the remediation where it is required and satisfy the Local Authority that the remediation has been carried out as agreed.

Additionally, Part 2A of the Environmental Protection Act 1990 requires that a significant source-pathway-receptor linkage exists to determine a site as contaminated land. This means that there has to be a contaminant present, a receptor that could be harmed by this contaminant, and a pathway linking the two. Part 2A deals with the contamination risk from a site in its current use, however, the planning system requires that the proposed use is considered. Where remediation is carried out under the planning system, it should be ensured that the site is in such a condition that it would still not meet the definition of contaminated land under Part 2A.

3.2 Preliminary Conceptual Site Model

A preliminary conceptual model has been compiled for the site with respect to the proposed scheme to identify the potential sources of contamination and the associated potential pollutant linkages.

3.2.1 Potential Sources

Potential contamination sources can include both current and historical activities on site and in the surrounding area. The following potential sources have been identified at the site.

- *Made Ground* – The golf course incorporates a number of raised mounds/features that may have been formed from reworked natural soils (i.e. as part of cut-fill operations), but may also include Made Ground material that may have been imported on to the site in order to create some of the landscaping features associated with the golf course. If present, Made Ground could be a potential source of contamination associated C&D-type materials, that may include metals, polycyclic aromatic hydrocarbons (PAHs) and potentially asbestos (typically associated with demolition materials). If the Made Ground and/or other infilled soils (including reworked natural soils) have a high organic content, a potential risk of ground gas may also be present. However,

as the mounds appear to be above-ground, then a viable risk of ground gas that may affect the proposed development is unlikely to be present.

- *Infilled quarry* – A quarry was previously recorded on the north-eastern margin of the site, and is no longer shown on maps dated from 1985. The quarry may have been infilled with Made Ground, which may be a source of polycyclic aromatic hydrocarbons (PAHs) and potentially asbestos. As per above, if infilled soils (including reworked natural soils) have a high organic content, a potential risk of ground gas may also be present. With reference to proposed development plans, included in Appendix A, the location of the quarry is within an area of proposed future car parking and therefore risks of contact between potentially infilled materials and future site end users, together with the anticipated ground gas migration risks, are considered less likely.

Surrounding land uses – information from the desk study indicates that the surrounding area has generally been agricultural land or residential use since the earliest available historical map edition. Infilled ground is present to the northeast of the site which may represent a potential source of ground gases that could migrate towards the site.

3.2.2 Potential Pathways

The potential migration pathways that may be present at the site include:

- *Ingestion* - contamination within Made Ground, if exposed during construction or in final development, may result in ingestion of contaminants.
- *Inhalation* – contamination within Made Ground, if exposed during construction or in final development, may result in inhalation of contaminated dust, including asbestos fibres (if present).
- *Direct contact* – contaminated soils in direct contact with building material can result in the permeation of contaminants
- *Dermal contact* – direct contact with contaminated soils can result in uptake of contaminants through the skin;
- *Root uptake* – uptake of phytotoxic contaminants can occur by plants and vegetation
- *Lateral and vertical migration* – leaching of contamination in the soils may impact groundwater, which can then flow both laterally and vertically. Whilst a viable migration pathway to groundwater is present, the site is not within a groundwater source protection zone. Given the

distance to the nearest sensitive water receptor, a potential migration pathway to surface water receptors from the anticipated contamination sources is unlikely to be valid; and

- *Ground gas migration* – migration of ground gases through the soil matrix could lead to accumulation within buildings, posing a risk of asphyxiation or explosion.

3.2.3 Potential Receptors

Based on the proposed end use of the site as a hotel, the main receptors at the site are considered to be:

- *Future site occupants* – considered to be at low risk from possible contamination associated with the identified sources on site and ground gas /vapour accumulation within buildings.
- *Construction workers* – primarily at risk from direct contact, inhalation or ingestion of contaminants during ground works;
- *Off-site residents* – potential contamination risks are anticipated to be very low assuming appropriate practices during construction as appropriate;
- Controlled waters – The Secondary A Aquifer of the Cornbrash Formation is considered to the primary controlled waters receptors, however, the site is not situated within a groundwater source protection zone and there are no known sensitive water abstractions within the vicinity of the site.
- *Buildings and infrastructure* – could be at risk from ground gas migration, aggressive ground conditions (including sulphates) and contaminants may permeate through and underground services such as water supply pipes; and
- Plants and vegetation – primarily at risk from phototoxic contaminants such as boron, copper, nickel and zinc.

3.3 Preliminary Qualitative Risk Assessment

A preliminary qualitative risk assessment has been undertaken based on the findings of the conceptual site model and the potential pollutant linkages that may exist at the site in accordance with Land Contamination Risk Management guidance[11]. Using criteria broadly based on those presented in CIRIA

[11] GOV.UK. 2021. *Land Contamination Risk Management (LCRM).* https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm [Accessed on 30/11/2021]

Report C552[12], the magnitude of the risk associated with potential pollutant linkages has then been assessed and is summarised in Table 2. The risk assessment methodology is presented in Appendix E.

Table 2. Preliminary Qualitative Risk Assessment

Potential Source/Medium	*Potential Exposure Route*	*Potential Receptor*	*Severity*	*Probability*	*Risk Rating*
Made Ground associated with re-profiling of site levels	Ingestion, inhalation, dermal contact	Future site occupants	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Off-site residents	Medium	Low likelihood	Moderate / Low
	Direct contact	Buildings and infrastructure	Mild	Low likelihood	Low
	Lateral and vertical migration	Groundwater (Secondary A Aquifer)	Medium	Low likelihood	Moderate / Low
		Surface Waters	Mild	Low likelihood	Low
	Ground gas migration	Buildings and infrastructure	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Future site occupants	Medium	Low likelihood	Moderate / Low
	Root uptake	Plants and vegetation	Minor	Low likelihood	Very low
Infilled Quarry (infilled materials)	Ingestion, inhalation, dermal contact	Future site occupants	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Off-site residents	Medium	Low likelihood	Moderate / Low
	Direct contact	Buildings and infrastructure	Mild	Low likelihood	Low
	Lateral and vertical migration	Groundwater (Secondary A Aquifer)	Medium	Low likelihood	Moderate / Low
		Surface Waters	Mild	Low likelihood	Low
	Ground gas migration	Buildings and infrastructure	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Future site occupants	Medium	Low likelihood	Moderate / Low
	Root uptake	Plants and vegetation	Minor	Low likelihood	Very low

[12] CIRIA. 2001. *Contaminated Land Risk Assessment. A guide to good practice*. C552.

4. GROUND INVESTIGATION

4.1 Site Work

An intrusive ground investigation was carried out by CGL between the 18th October and 2nd November 2021, and comprised the following:

- Drilling of twelve rotary cored boreholes to depths of between 3.0m and 20.0mbgl, drilled using a Comacchio GEO 305 drilling rig with recycled water flush.
- Installation of groundwater monitoring standpipes and standpipe piezometers within all boreholes
- Installation of groundwater monitoring divers within seven boreholes; and
- The completion of groundwater monitoring visits.

Prior to drilling, hand-dug inspection pits were dug to depths of between 0.6 m and 1.2 m (where hand-dug methods refused). On completion, all boreholes were installed with monitoring standpipes as described in Section 4.2 of this report.

The depths for each exploratory hole are presented in Table 3. An exploratory hole location plan in presented as Figure 3 and the exploratory hole logs are included in Appendix F. Photographs of borehole core recovery are shown in Appendix G.

Table 3. Summary of exploratory hole locations

Location ID	*Easting (m)*	*Northing (m)*	*Level*	*Final Depth (m)*	*Termination Reason*
BH01	454,854.630	221,796.740	84.83	5.00	Achieved target depth
BH02	454,804.240	221,684.950	84.75	5.00	Achieved target depth
BH03	454,918.030	221,726.240	83.74	5.00	Achieved target depth
BH04	454,833.110	221,561.800	83.52	20.00	Achieved target depth
BH05	454,945.450	221,610.860	82.30	13.00	Achieved target depth
BH06	455,036.770	221,630.660	82.19	5.00	Achieved target depth
BH07	454,836.030	221,483.970	81.83	5.00	Achieved target depth
BH08	455,034.000	221,569.560	81.27	3.10	Achieved target depth
BH09	455,190.450	221,612.430	81.41	3.00	Achieved target depth
BH10	455,233.900	221,667.420	81.08	3.00	Achieved target depth
BH11	454,862.390	221,401.940	81.31	3.00	Achieved target depth
BH12	454,955.450	221,451.910	80.59	3.00	Achieved target depth

The rationale for the investigation was to gather information on the geological profile of the site, investigate groundwater depths and hydrogeological conditions, undertake in-situ testing and collect samples for chemical and geotechnical laboratory testing. The scope of works and exploratory hole locations were agreed following the site walkover completed on 18th October 2021.

Prior to commencing the intrusive works each exploratory hole location was cleared for buried services using a cable avoidance tool (CAT) survey and signal generator in accordance with HSG47[13]. The exploratory hole locations were surveyed as part of the investigation to provide information on the easting, northing and levels. The investigation was undertaken in general accordance with the requirements of BS 5930:2020[14] and BS 10175:2011+A2:2017[15]. The exploratory hole arisings were logged and representatively sampled collected by suitably qualified engineers from CGL.

Samples were taken for chemical and geotechnical laboratory testing to characterise the ground conditions encountered at the site and assess potential contamination. Standard Penetration Tests (SPTs) were undertaken within the rotary percussion boreholes within soils.

4.2 Monitoring Installations

All twelve of the rotary core boreholes were installed with groundwater monitoring wells, as summarised in Table 4.

Table 4. Summary of monitoring installations

Location ID	*Date of installation*	*Top of Response Zone Depth in (m bgl) Level in [m AOD]*	*Base of Response Zone Depth in (m bgl) Level in [m AOD]*	*Pipe Diameter (mm)*	*Response Zone Strata*
BH01	19/10/2021	1.00 [83.83]	5.00 [79.83]	50	Weathered Cornbrash Formation and Forest Marble Formation (clay, limestone and mudstone)
BH02	19/10/2021	1.00 [83.75]	5.00 [79.75	50	Weathered Cornbrash Formation, Cornbrash Formation (limestone), and Forest Marble Formation (clay, limestone and mudstone)
BH03 Dual Install	25/10/2021	1.00 [82.74]	3.50 [80.24]	50	Weathered Cornbrash Formation, Cornbrash Formation (limestone), and Forest Marble Formation (mudstone)
		4.00 [79.74]	5.00 [78.74]	19	Forest Marble Formation (limestone and mudstone)
BH04 Dual Install	29/10/2021	1.50 [82.02]	4.00 [79.52]	50	Weathered Cornbrash Formation, Cornbrash Formation (limestone), and Forest Marble Formation (clay and mudstone)

[13] HSE (2014) *Avoiding the danger from underground services (HSG47).*
[14] British Standards Institution. (2020). *Code of practice for site investigations*. BS5930:2015 + A1:2020.
[15] British Standards Institution. (2017). *Investigation of potentially contaminated sites: Code of practice.* BS10175:2011+A2:2017.

Location ID	*Date of installation*	*Top of Response Zone Depth in (m bgl) Level in [m AOD]*	*Base of Response Zone Depth in (m bgl) Level in [m AOD]*	*Pipe Diameter (mm)*	*Response Zone Strata*
		5.50 [78.02]	10.00 [73.52]	19	Forest Marble Formation (mudstone, limestone and clay)
BH05 Dual Install	25/10/2021	4.20 [78.10]	10.0 [72.30]	50	Forest Marble Formation (mudstone, limestone and clay)
		.1.0 [81.3]	2.50 [79.80]	19	Weathered Cornbrash Formation, Cornbrash Formation (limestone), and Forest Marble Formation (clay and mudstone)
BH06	19/10/2021	1.00 [81.19]	5.00 [77.19]	50	Weathered Cornbrash Formation, Cornbrash Formation (limestone), and Forest Marble Formation (limestone and mudstone)
BH07	19/10/2021	1.00 [80.83]	5.00 [76.83]	50	Cornbrash Formation
BH08	19/10/2021	1.00 [80.27]	3.00 [78.27]	50	Cornbrash Formation
BH09	19/10/2021	1.00 [80.41]	3.00 [78.41]	50	Weathered Cornbrash Formation and Forest Marble Formation (clay and mudstone)
BH10	19/10/2021	1.00 [80.08]	3.00 [78.08]	50	Weathered Cornbrash Formation and Cornbrash Formation (limestone)
BH11	19/10/2021	1.00 [80.31]	3.00 [78.31]	50	Cornbrash Formation and Forest Marble Formation (mudstone)
BH12	19/10/2021	1.00 [79.59]	3.00 [77.59]	50	Cornbrash Formation and Forest Marble Formation (clay)

To date, two monitoring visits have been undertaken on 11th November 2021 and 16th December 2021 to record groundwater levels and recover data from groundwater monitoring loggers. The results of monitoring are summarised in Section 5, below.

4.3 Chemical Testing

Representative soil and water samples were sent to i2 Analytical Limited (a UKAS and MCERTS accredited laboratory) for chemical testing. These consisted of environmental samples which were filled and compacted into the relevant containers to minimise headspace. The samples taken for chemical laboratory testing were stored and transported in accordance with BS ISO 18400-105:2017[16]. The soil analysis included the following contaminants:

- Soil Organic Matter (SOM)

[16] British Standards Institution (2017). *Soil quality. Sampling. Packaging, transport, storage and preservation of samples.* BS ISO 18400-105.

- Heavy metals including; arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Total Petroleum Hydrocarbons Criteria Working Group (TPH CWG);
- Polycyclic Aromatic Hydrocarbons (PAH);
- BTEX compounds (benzene, toluene, ethylbenzene and xylenes);
- Total monohydric phenols; and
- Total cyanide

Selected samples of Made Ground were also screened for asbestos using laboratory microscopy.

The chemical analysis laboratory results are presented in Appendix H.

4.4 Geotechnical Testing

Representative soil and rock core samples were sent i2 Analytical Limited for geotechnical testing. The following tests were scheduled at the geotechnical laboratory:

- Moisture content;
- Particle Size Distribution (PSD);
- Atterberg Limit;
- Quick undrained single-stage triaxial tests;
- Point load index of rock
- Unconfined Compressive Strength (UCS) of rock; and
- Building Research Establishment (BRE) Special Digest[17] (SD) Suite – including 2:1 water soluble sulfate, total sulfate, total sulfur and pH.

The results of the geotechnical laboratory testing are presented in Appendix I.

[17] Building Research Establishment. (2006). *BRE Special Digest Part 1: Concrete in aggressive ground*.

5. GROUND AND GROUNDWATER CONDITIONS

5.1 Summary

The ground conditions encountered during the CGL site investigation are summarised in Table 5. The observed strata are discussed separately in the following sections, together with the results of in-situ and geotechnical laboratory tests. Plots of SPT values, undrained shear strength against level, UCS values against level and a Plasticity Index Chart are presented in Figures 4 to 10.

Photographs of the core from each borehole location are included as Appendix G.

Table 5. Summary of Ground Conditions Encountered During Site Investigation

Formation Name	*Depth to top of stratum (m bgl) [Level to top of stratum (m AOD)]*	*Range of Thicknesses (m)*
[TOPSOIL]	0.00 [80.59 – 84.83]	0.1 - 0.4
[WEATHERED CORNBRASH FORMATION]	0.10 – 0.40 [84.65 – 80.39]	0.50 - 2.05
[CORNBRASH FORMATION]	0.80 – 2.25 [82.83 – 78.98]	0.20 – 1.70
[FOREST MARBLE FORMATION]	1.95 – 3.05 [82.83 – 78.59]	0.75 - 17.45*

**Base not proven*

5.2 Visual and Olfactory Evidence of Contamination

Significant visual or olfactory evidence of contamination was not noted within the areas investigated during the ground investigation works.

5.3 Topsoil

Topsoil was encountered in all twelve exploratory locations and generally consisted of soft dark brown clay, occasionally sandy and gravelly. The gravel was described as fine to coarse sub-angular to sub-rounded limestone. The thickness of Topsoil ranged from to 0.10 m to 0.40m.

5.4 Cornbrash Formation

According to the BGS description, the Cornbrash Formation is a fine to medium grained limestone which weathers to a yellowish brown[18]. The base of the Cornbrash is described as being a cream-coloured fossiliferous limestone[19]. It overlies the Forest Marble Formation (described in Section 5.4)

[18] British Geological Survey (BGS). 2021. *The BGS Lexicon of Named Rock Units – Cornbrash Formation.* BGS Lexicon of Named Rock Units - Result Details [Accessed 22/11/2021].
[19] Arkell, W. J. (1933). *The Jurassic System in Great Britain*. Clarendon Press.

and the change in strata is indicated by a change in colour from light brown of the Cornbrash to dark grey of the Forest Marble Formation. For the purposes of this report, the Cornbrash Formation has been split into the weathered 'residual soils', oolitic limestones/marls, and limestone as described below.

5.4.1 Weathered Cornbrash Formation

Beneath the topsoil, weathered 'residual soil'[20] of the Cornbrash Formation is present, described as generally comprising light to dark brown sandy gravelly clay or clayey gravel. The gravel was described as fine to coarse sub-angular to angular limestone. These residual soils were encountered, beneath the topsoil, in all twelve borehole locations and the elevation of the base of these soils ranged from 84.15 – 78.59 m AOD, and the thickness ranged from 0.50 m in BH02 to 2.20 m in BH06.

Eleven SPT tests were carried out in this horizon between depths of 0.60 m and 2.0 m bgl, with SPT 'N' values of between 6 and 50 and the average N value across this stratum was 27.

5.4.2 Oolitic Limestone and Marl

Oolitic limestone or marl was encountered in three exploratory hole locations (BH04, BH05, BH07) beneath the residual soils of the Cornbrash Formation and overlying limestone of the Cornbrash Formation. Generally, the marl was described as clayey gravelly sand with oolitic limestone lithorelics or weak grey mottled orangish brown fine to medium grained limestone with spherical nodules, and sand sized grains of oolites and calcite crystals. The elevation of the base of the marls ranged from 81.57 m AOD in BH04 and 79.93 m AOD in BH07, and the thickness ranged from 1.25 m to 1.40 m.

A total of 8 point index strength tests were undertaken on samples of marl, including 2 diametral tests, 4 axial tests and 2 tests undertaken on irregular lumps (Figure 8). The following values were recorded:

- Point Load Indices $Is_{(50)}$ values for diametral tests on the marl ranged between 0.11 MPa and 0.43 MPa, corresponding to approximate UCS values of 2.31 MPa to 9.03 MPa corresponding to strength descriptors of 'very weak' to 'weak' assuming a (multiplier of 21[21,22]).

- Point Load Indices $Is_{(50)}$ values for axial and irregular tests on the marl ranged between 0.22 MPa and 2.22 MPa, corresponding to approximate UCS values of 4.62 MPa to 46.62 MPa

[20] British Standards Institution. (2020). *Code of practice for site investigations*. BS5930:2015 + A1:2020.
[21] International Journal of Rock Mechanics. (1985). *Suggested method to determine the point load index strength*. Vol 22 pp 51 -60.
[22] Chau, K. T., & Wong, R. H. C. (1996, February). Uniaxial compressive strength and point load strength of rocks. In International journal of rock mechanics and mining sciences & geomechanics abstracts (Vol. 33, No. 2, pp. 183-188). Pergamon.

corresponding to strength descriptors of 'very weak' to 'medium strong' assuming a (multiplier of 21).

5.4.3 Limestone

Limestone of the Cornbrash Formation was encountered in eight exploratory hole locations across the site. The limestone was described as medium strong to strong light brown and light grey medium grained thinly bedded slightly fractured fossiliferous limestone. Fractures were generally horizontal and slightly weathered with occasional orange staining indicating that water has flowed through them. The shallowest elevation of the top of this limestone was 83.41 m AOD in BH02. The thickness ranged from 0.20 to 1.70 m, with an average thickness of 0.7 m.

A total of two point index strength tests were undertaken on samples of Cornbrash Formation limestones, including 1 axial tests and 1 test undertaken on irregular lumps (Figure 9). The following values were recorded:

- Point Load Indices $Is_{(50)}$ values for axial and irregular tests on the limestone ranged between 0.20 MPa and 2.51 MPa, corresponding to approximate UCS values of 4.20 MPa to 52.71 MPa corresponding to strength descriptors of 'very weak' to 'strong' assuming a (multiplier of 21).

5.5 Forest Marble Formation

The Forest Marble Formation is described by the BGS as greenish grey silicate mudstone with interbedded grey limestone units[23]. The upper boundary is described as mudstone sharply overlain by the Cornbrash Formation. On this site the Forest Marble Formation was recorded to typically comprise interbedded clays, mudstone, and limestone, which are described in the sections below.

As described above, the change in colour, from light brown to dark grey, has been used to determine the boundary between these two strata. Generally, at this site the top of the Forest Marble Formation is marked by either a layer of stiff dark grey clay or grey mudstone. The shallowest elevation that the Forest Marble Formation was encountered was 79.11 m AOD in BH11.

The Forest Marble Formation was encountered in all exploratory holes apart from BH10.

[23] British Geological Survey (BGS). 2021. *The BGS Lexicon of Named Rock Units – Forest Marble Formation.* BGS Lexicon of Named Rock Units - Result Details [Accessed 22/11/2021].

5.5.1 Clay

The top of the Forest Marble Formation was marked in seven boreholes by a bed of stiff to very stiff dark grey to bluish grey occasionally slightly sand or slightly silty clay. The shallowest elevation depth of this top clay bed was 82.83 m AOD, with the top clay bed having an average thickness of 0.77 m.

Beds of clay were encountered at depth in nine boreholes with a range of thicknesses from 0.20m to 1.20m. The thickness generally decreased with depth. The deepest bed of clay was encountered in BH04 at a depth of 16.77 m bgl (66.75 m AOD) and was 0.30 m thick.

Fourteen SPT tests were carried out in the clay between depths recording SPT 'N' value ranging between 6 and 50, with an average of 35. It should be noted that the 'N' values of 6 recorded in BH01 at 4.7 m bgl is likely to have been caused by drilling disturbance and interaction with water levels/water introduced into the ground during drilling, and may not be representative of in-situ conditions.

A total of 15 point load index strength tests were undertaken on cohesive samples of Forest Marble Formation, including 3 diametral tests and 7 axial tests (Figure 9). The following values were recorded:

- Point Load Indices $Is_{(50)}$ values for diametral tests ranged between 0.03 MPa and 0.22 MPa, corresponding to approximate UCS values of 0.63 MPa to 4.62 MPa corresponding to strength descriptors of 'extremely weak' to 'weak' assuming a (multiplier of 21[24,25]).

- Point Load Indices $Is_{(50)}$ values for axial tests ranged between 0.06 MPa and 0.38 MPa, corresponding to approximate UCS values of 1.26 MPa to 7.98 MPa corresponding to strength descriptors of 'very weak' to 'weak' assuming a (multiplier of 21).

5.5.2 Mudstone

The top of the Forest Marble Formation was marked in four boreholes by layer of extremely weak to weak dark grey to blue grey slightly silty fine-grained mudstone. The shallowest depth of this mudstone was 1.95 m bgl, and the bed had an average thickness of 0.80 m.

Thirteen SPT tests were carried out in this layer of mudstone, recording SPT 'N' values of 32 and 50, with an average N value of 46.

[24] International Journal of Rock Mechanics. (1985). *Suggested method to determine the point load index strength*. Vol 22 pp 51 -60.

[25] Chau, K. T., & Wong, R. H. C. (1996, February). Uniaxial compressive strength and point load strength of rocks. In International journal of rock mechanics and mining sciences & geomechanics abstracts (Vol. 33, No. 2, pp. 183-188). Pergamon.

5.5.3 Limestone

The limestone of the Forest Marble Formation was generally described as strong light grey to dark grey, fine to medium grained fossiliferous limestone occasionally with green staining. The fractures within the limestone were often stained orange, both on fracture planes and also with an orange-staining penetration of several mm on either side of the fractures, suggesting water flow.

In the deeper boreholes (BH04 and BH05) the underlying formation of the White Limestone may have been reached, but the boundary between the this stratum and the Forest Marble Formation has not yet been determined.

Three SPT tests were carried out in the limestone of the Forest Marble Formation and all recorded SPT 'N' values 50.

A total of 18 point index strength tests were undertaken on limestone samples of the Forest Marble Formation, including 7 diametral tests and 11 axial tests (Figure 9). The following values were recorded:

- Point Load Indices $Is_{(50)}$ values for diametral tests ranged between 1.51 MPa and 4.69 MPa, corresponding to approximate UCS values of 31.71 MPa to 98.49 MPa corresponding to strength descriptors of 'medium strong' to 'strong' assuming a (multiplier of 21[26,27]).

- Point Load Indices $Is_{(50)}$ values for axial tests ranged between 0.76 MPa and 4.51 MPa, corresponding to approximate UCS values of 15.96 MPa to 94.71 MPa corresponding to strength descriptors of 'weak' to 'strong' assuming a (multiplier of 21).

5.6 Groundwater Conditions

Water strikes were encountered in four borehole locations during the investigation (BH02, BH03, BH04, and BH07) within the Cornbrash Formation and the Forest Marble Formation, as summarised in Table 6.

Table 6. Summary of water strikes

Location	*Depth of groundwater strike*	*Stratum*
BH02	3.50m bgl.	In Clay between 3.50m bgl and 3.90m bgl [CORNBRASH FORMAITON]
BH03	1.65m bgl.	In Clay between 1.20m bgl and 1.70m bgl [WEATHERED CORNBRASH FORMATION]
BH03	3.50m bgl.	In Mudstone between 3.45m bgl and 3.78m bgl [FOREST MARBLE FORMATION]
BH04	7.00m bgl.	In Mudstone between 7.00m bgl and 7.05m bgl [FOREST MARBLE FORMATION]

[26] International Journal of Rock Mechanics. (1985). *Suggested method to determine the point load index strength*. Vol 22 pp 51 -60.

[27] Chau, K. T., & Wong, R. H. C. (1996, February). Uniaxial compressive strength and point load strength of rocks. In International journal of rock mechanics and mining sciences & geomechanics abstracts (Vol. 33, No. 2, pp. 183-188). Pergamon.

Location	*Depth of groundwater strike*	*Stratum*
BH07	4.40m bgl.	In Clay between 4.40m bgl and 4.76m bgl [FOREST MARBLE FORMATION]
BH07	4.60m bgl.	In Clay between 4.40m bgl and 4.76m bgl [FOREST MARBLE FORMATION]

During the investigation the water level in boreholes BH01, BH02, BH06, BH08-10 were recorded on 22nd and 25th October, the results of which are shown in Table 7.

Table 7. Groundwater Levels Recorded During Site Investigation

Borehole Location	*Groundwater Levels during Site Investigation*	
	22/10/2021	*25/10/2021*
	Depth to Water (m bgl) [m AOD]	*Depth to Water (m bgl) [m AOD]*
BH01	0.89 [83.94]	1.05 [83.78]
BH02	-	1.81 [82.94]
BH06	1.85 [80.34]	1.92 [80.27]
BH08	1.32 [79.95]	1.70 [79.57]
BH09	1.26 [80.15]	1.53 [79.88]
BH10	1.48 [79.60]	1.34 [79.74]

5.6.1 Continuous Groundwater Monitoring

Continuous groundwater monitoring data loggers were installed within BH01, BH04, BH05, BH07, BH08, BH10 and BH11 on 11th November 2021. Data was collected between 11th November 2021 and 7th February 2022. Table 8 presents a summary of the data and the groundwater levels are plotted against daily rainfall in Figures 12 to 14. A summary of all the data against precipitation is presented as Figure 14.

When compared to the daily rainfall data, the groundwater shows quite a fast response to a rainfall event – the levels rise quickly immediately after the rainfall event. The water levels then stay at a higher level for an extended period of time, indicating that the groundwater is not freely draining away – this could be related to the bands of clay within the Forest Marble Formation.

Table 8. Summary of Groundwater Logging Data

Borehole Location	Depth of Monitoring Well (m bgl)	Depth to Groundwater 11/11/21 – 08/02/22	
		Minimum (m bgl) [mOD]	Maximum (m bgl) [mOD]
BH01	5.00	0.52 [84.31]	1.22 [83.61]
BH04	3.98	0.84 [82.68]	1.98 [81.54]
BH05	9.90	1.49 [80.81]	2.20 [80.1]
BH07	4.30	0.65 [80.18]	2.39 [79.44]
BH08	3.00	0.40 [80.87]	1.72 [79.55]
BH10	2.95	0.17 [80.91]	1.54 [79.54]
BH11	3.12	0.43 [80.88]	1.62 [79.69]

5.7 Rising Head Permeability Tests

Rising Head Permeability Tests were undertaken in BH04 and BH07 on 8th February 2022. The results are summarised in Table 9. Full results are included in Appendix F.

Due to the recharge rate of the water within boreholes, it was not possible to fully purge the wells (to "dry") prior to recording of rising head values.

Table 9. Rising Head Permeability Tests (estimated)

Borehole Location	Well Depth (m bgl)	Estimated Permeability (k) (m/s)
BH04	4.0	3.105×10^{6}
BH07	4.3	8.366×10^{6}

5.8 Ground Gas Monitoring

A single ground gas monitoring visit was carried out on 16th December 2021 during an atmospheric pressure event of 1028mb. A summary of the data recorded during the monitoring visits is presented in Table 10.

Table 10. Summary of Gas Monitoring

Borehole Location	Steady Flow Rate (l/hr)	Minimum O_2 (% volume in air)	Residual CO_2 (% volume in air)	Maximum CH_4 (% volume in air)
BH02	0.1	19.3	<0.1	<0.1
BH03*	0.1	15.6	1.7	<0.1
BH12	0.1	8.9	4.2	<0.1

***Note**: Elevated flow readings were recorded during the visit within BH03. However, given that water was recorded at 0.65mbgl (within the "plain" section of the pipe), it is considered that the monitoring pipe is "flooded", and flow readings recorded are likely to be associated with a "piston" effect from groundwater. As such, a steady flow rate of 0.1l/hr has been adopted. Further monitoring will be undertaken to confirm this assessment.

5.9 Geotechnical Testing Results

Based on the results of the in-situ and laboratory testing a summary of the geotechnical properties of the soils is presented in Table 11. The results of the geotechnical laboratory testing are presented in Appendix G and presented graphically in Figures 4 to 10 inclusive.

Table 11. Summary of Geotechnical Test Data

SPT 'N' data[a]			
Strata	***Range (No. of tests) [mean]***	***Undrained Shear Strength (kN/m^2)***	***Classification***
Weathered Cornbrash Formation (residual soils)	6 to >50 (11) [27]	27 to >225	Low strength to Very high strength
Cornbrash Formation Marl	6 to >50 (3) [28]	27 to >225	Low strength to Very high strength
Cornbrash Formation Limestone	20 to >50 (7) [41]	90 to >225	High Strength to Very high strength
Forest Marble Formation – Clay	6 to >50 (14) [35]	27 to >225	Low strength to Very high strength
Forest Marble Formation– Mudstone	32 to >50 (13) [46]	144 to >225	Low strength to Very high strength
Forest Marble Formation– Limestone	>50 (3) [50]	>225	Very high strength

Undrained triaxial strength tests		
Strata	***Undrained shear strength range - c_u (kPa) [no of tests]***	***Classification***
Forest Marble Formation – Clay	60 - 587 (3)	Strong to Extremely Strong

Atterberg Limits						
Strata	***Moisture content (%)***	***Liquid Limit (%)***	***Plastic Limit (%)***	***% material <425µm***	***Modified Plasticity Index***	***Volume change potential***
Weathered Cornbrash Formation (residual soils)	10 – 19	26 – 50	13 – 26	29 – 100	6.83 – 18.9	Low to Medium
Forest Marble Formation – Clay	15 – 30	24 - 58	15 – 29	84 – 92	8.28 - 24	Low to High
Forest Marble Formation– Mudstone	9.9 - 15	28 - 40	15 -19	100	13 -21	Medium to High

Particle size distribution						
Strata	***Number of Tests***	***Clay/Silt (%)***	***Sand (%)***	***Gravel (%)***	***Cobbles (%)***	***Notes***
Weathered Cornbrash Formation (residual soils)	7	4 – 46	12 – 29	19 – 79	0 – 10	

5.9.1 Rock Quality/Coring

Rock cores were recorded from boreholes during rotary coring operations. A summary of the cored depths, total core recover (TCR), solid core recovery (SCR) and corresponding Rock Quality Designation (RQD) are summarised in Table 12.

Table 12. Summary of Coring Quality Measurements

BH ID	*Cored depths (m)*	*Range of Total Core Recovery (TCR) (%)*	*Range of Solid Core Recovery (SCR) (%)*	*Range of Rock Quality Designation (%)*	*Fracture spacing range (mm) [average]*
BH01	1.2 - 5.0	67 - 100	0 - 40	0 - 44	-
BH02	0.6 - 5.0	43 – 100	6 – 73	0 – 61	40 - 200 [98]
BH03	1.2 – 5.0	87 - 100	16 - 100	0 - 100	-
BH04	0.7 – 20.0	25 - 100	0 - 100	0 - 100	50 – 600 [216]
BH05	1.2 – 13.0	25 - 100	-	-	10 – 650 [200]
BH06	0.9 – 5.0	87 – 100	0 – 62	0 – 7	20 – 560 [155]
BH07	0.6 – 5.0	80 – 100	93 - 100	16 - 40	30 – 210 [72]
BH08	1.2 – 3.0	93 – 100	0	0	-
BH09	1.2 – 3.0	100	0 – 22	0	60 - 90 [75]
BH10	1.2 – 3.0	86 – 100	0 – 86	0 – 14	40 – 300 [100]
BH11	0.8 – 3.0	80 – 100	0 – 86	0 – 14	-
BH12	0.8 – 3.0	100	0	0	-

5.10 Ground Model

The ground conditions encountered at this site consist of topsoil underlain by the Cornbrash Formation to a maximum depth of 3 m bgl, which is in turn underlain by the Forest Marble Formation, as summarised below:

- Topsoil was encountered at all locations with a thickness of between 0.1 and 0.4 m. The elevation of the base of the topsoil ranged from 84.65 – 80.39 m AOD.

<u>Cornbrash Formation</u>

- Residual soils of the Weathered Cornbrash Formation were encountered at all borehole locations and consisted of dark to light brown sandy gravelly clay or clayey gravel. The elevation of the base of these soils ranged from 84.15 –78.59 m AOD, and the thickness ranged from 0.50 m in BH02 to 2.20 m in BH06.

- Marl of the Cornbrash Formation was encountered beneath the residual soils in three boreholes (BH04, BH05, and BH07). Generally, the marl was described as clayey gravelly sand with oolitic limestone lithorelics or weak grey mottled orangish brown fine to medium grained limestone with spherical nodules, and sand sized grains of oolites and calcite crystals. The elevation of the base of the marls ranged from 81.57 m AOD in BH04 and 79.93 m AOD in BH07, and the thickness ranged from 1.25 m to 1.40 m.

- Limestone of the Cornbrash Formation was encountered in eight exploratory hole locations (boreholes BH02 to BH07, BH10 and BH11). The limestone was described as medium strong to strong light brown and light grey medium grained thinly bedded slightly fractured fossiliferous limestone. The elevation of the base of the limestone ranged from 81.79 m AOD in BH03 and 78.08 m AOD in BH10, and the thickness ranged from 0.20 m to 1.70 m.

Forest Marble Formation

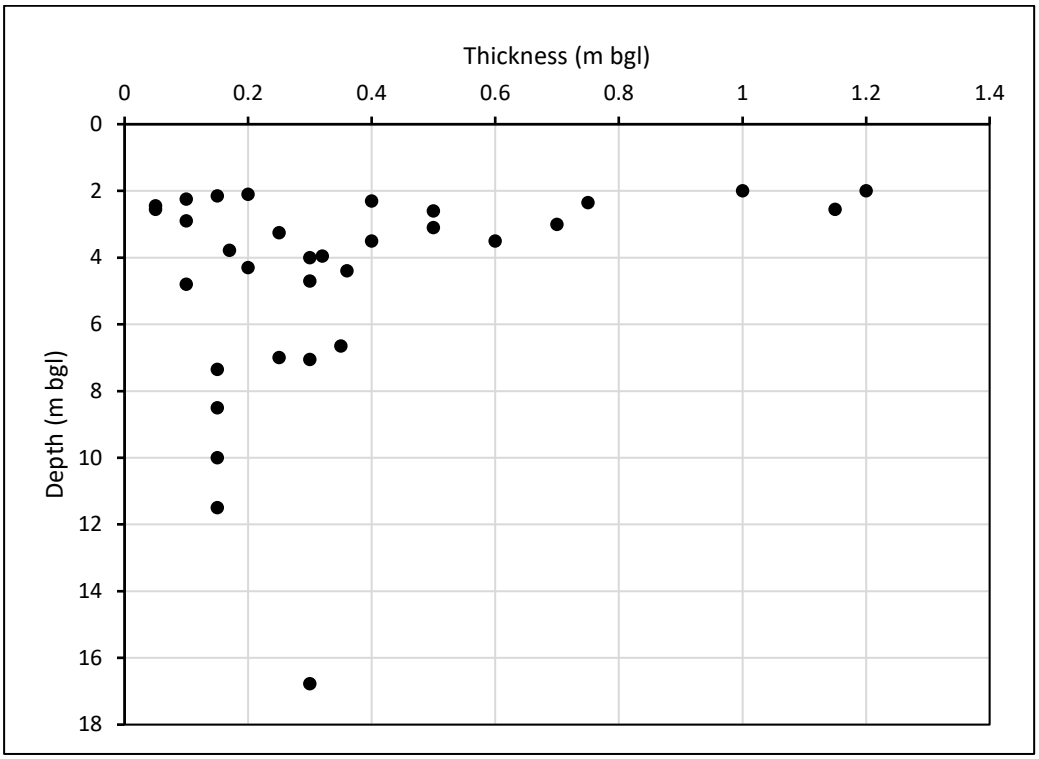
The Forest Marble Formation comprises of interbedded bands of clay, mudstone, and limestone.

- Stiff to very stiff dark grey to bluish grey clay of the Forest Marble Formation was encountered in nine boreholes (boreholes BH01, BH02, BH04, BH05, BH06, BH07, BH08, BH09 and BH12) at a minimum elevation of 78.59 m AOD in BH12. The clay beds range in thickness from 0.05 m to 1.20 m, with and average thickness of 0.30 m. Generally, the thickness of the bands decreases with depth, as shown in the below graph displayed in Plate 4.

- Extremely weak to weak dark grey to blue grey slightly silty fine-grained mudstone was encountered in eight boreholes (BH01 to BH07 and BH11) locations at a minimum elevation of 79.11 m AOD in BH11. The bands of mudstone range in thickness from 0.05 m to 1.25 m with an average thickness of 0.35 m.

- Limestone was encountered in nine borehole locations (BH01 to BH06 and BH09) at a minimum elevation of 78.49 m AOD in BH06. Generally, the limestone was described as being strong light grey to dark grey fine to medium grained thinly bedded fossiliferous limestone. The thickness of the bands of limestone ranged from 0.04 to 1.10 m with an average thickness of 0.4 m.

Plate 4. Thicknesses of Cohesive Beds vs Depth



Groundwater

Shallow groundwater was encountered across the site during at elevations ranging from 84.31 to 78.28 m AOD, with a deeper water horizon present at depths of between 4.3m and 4.72mbgl in the lower limestone (and indicated to be separated from the shallower groundwater by a bed of clay/mudstone). Groundwater is indicated to be flowing from the north to the south across the site.

6. CONTAMINATION ASSESSMENT

6.1 Introduction

This section of the report evaluates risks to potential receptors at the site from identified chemical contamination. Potential receptors have been identified with reference to the Part 2A regime and associated Defra guidance[28]. As part of the Part 2A regime, under the planning regime all receptors (humans, controlled waters, vegetation and buildings) have been considered if there is the potential for them to be adversely affected by exposure to contamination. CGL's approach and rationale to assessment criteria adoption for this site is presented in Table J1 of Appendix J.

6.2 Risk to Human Health

It is understood that the proposed development comprises the construction of a new hotel and water park together with associated parking landscaping and infrastructure. The laboratory test results have been compared against a Generic Assessment Criteria (GAC) that have been derived in-house by CGL for a "commercial" land use category to assess the risks to human health from contamination present in soils. The results of the chemical assessment are presented in Table J2 and J3 of Appendix J.

6.3 Topsoil and Natural Soils

Four samples of topsoil and eleven samples of natural soils were obtained during the ground investigation and were analysed for a range of determinants. When compared against the relevant GAC, concentrations of all potential contaminants are below the assessment criteria.

Twelve samples were screened for asbestos and the testing did not record the presence of asbestos within the samples.

6.4 Risks from Ground Gases

As identified in Section 3, a potential risk of ground gas may be present from Made Ground and/or infilled features (if present). Made Ground was not encountered during the works, however Made Ground materials may be present in other parts of the site not yet investigated. As part of returning monitoring visits, a single confirmatory ground gas monitoring reading was undertaken on 16th December 2021, with ground gas readings taken from selected boreholes (including BH03, situated closest to the former quarry). The results of monitoring are summarised below.

[28] DEFRA. (2012). *Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance*. Department for Environment, Food and Rural Affairs.

To further characterise the gas regime, the gas screening value (GSV) has been calculated, for the bulk gases, methane and carbon dioxide, using the following equation:

GSV = borehole flow rate (l/h) x gas concentration (%)

For this site, the "worst credible" approach is adopted for calculating the GSV. The "worst credible" GSV is calculated by assessing the data from the return monitoring visits for each gas and adopting the highest GSV. The "worst credible" GSVs are presented in Table 13 below.

Table 13. Ground Gas Assessment

Gas	*Peak Flow (l/hour)*	*Peak Concentration (%)*	*Steady State Concentration (%)*	*GSV*	*Characteristic Situation*
Carbon Dioxide	0.1	-	4.2	0.0042	CS1
Methane	0.1	0.1	-	0.0001	CS1

A semi quantitative assessment has been completed using the gas monitoring data to assess the ground gas regime at the site using the Characteristic Situation (CS).

Based on the concentrations and flow rates recorded during the three rounds of monitoring completed, the ground gas regime for the site is assessed to be CS1 based on the calculated GSV.

The site is located in an area where less than 1% of properties are affected by radon, therefore radon protection measures are not required.

The gas regime is assessed to be a **low** risk from bulk gases and a **low** risk from Radon.

6.5 Risk to Controlled Waters

Five soil samples were recovered for soil leachate testing to assess potential risks to controlled waters. As a first tier of assessment, chemical testing results from soil leachate samples were directly compared to Environmental Quality Standards (EQS) for freshwater receptors and Drinking Water Values (DWV). The results of the chemical assessment are presented in Table J4 of Appendix J.

When compared to EQS and DWV values, concentrations of all contaminants were recorded below relevant criteria values.

6.6 Risk to Plants and Vegetation

Plant growth can be affected by phytotoxic contaminants, such as copper, nickel, and zinc. The concentrations of the contaminants within the tested samples of topsoil and natural soils were all recorded below the phytotoxic assessment criteria (Table J5a and J5b of Appendix J).

6.7 Risk to Buildings and Infrastructure

6.7.1 Water Supply Pipes

With reference to the UK Water Industry Research Guidance[29] and based on the results obtained it is considered that special precautions are not likely to be required based on the contaminant concentrations recorded. The risks to water supply pipes are considered to be **low**. However, water supply pipe requirements should be confirmed with the Water Authority.

6.7.2 Sulphate and pH Conditions

Chemical analysis has been undertaken of samples of the natural soils in accordance with BRE SD1[30] to determine concrete classification. A summary of the results and the concrete classification is presented in Table 14 below.

Table 14 - Summary of Concrete Classification

Strata	*Details*	*Range*	*Classification based on Water Soluble Sulphate*	*Classification based on TPS/OS*
Weathered/Residual (clay/gravel)	Number of tests	8	DS – 1 AC1	DS1-AC1
	Water Soluble Sulfate (mg/l)	6 to 16		
	Total Potential Sulphate (%)	0.102 to 1.153		
	pH	8.3 to 8.8		
Mudstone/Clay	Number of tests	8	DS – 1 AC1	DS5-AC5
	Water Soluble Sulfate (mg/l)	13 to 310		
	Total Potential Sulphate (%)	0.09 to 3.3		
	pH	8.1 to 9.0		
Limestone	Number of tests	2	DS – 1 AC1	DS1-AC1
	Water Soluble Sulfate (mg/l)	7.8 to 17		
	Total Potential Sulphate (%)	0.105 to 0.156		
	pH	8.2 to 9.0		

Note:

a) Of eight samples; two are classified as DS1-AC1, one is DS2-AC2, one is DS3-AC3, two are DS4-AC4 and one sample (BH05 at 4.0mbgl) is DS5-AC5. Based on the number of tests and the location/depth of this sample, a classification of DS5-AC5 is considered appropriate. Further testing may be undertaken to further characterise the concrete classification designation.

The risk to buried concrete from the Made Ground and the Northmoor Sand and Gravel Member are assessed to be Low. The risk to buried concrete from the Oxford Clay Formation is assessed to be **Moderate / Low**.

[29] UK Water Industry Research. 2010. *Guidance for the selection of water supply pipes to be used in brownfield sites.*
[30] BRE. Special Digest 1, 2005. *Concrete in aggressive ground.*

6.8 Revised Qualitative Risk Assessment

The preliminary qualitative risk assessment has been updated on the findings of the ground investigation and the potential pollutant linkages that may exist at the site in accordance with Land Contamination Risk Management guidance[31]. Using criteria broadly based on those presented in CIRIA Report C552[32], the magnitude of the risk associated with potential pollutant linkages has then been assessed and is summarised in Table 15.

Table 15. Revised Qualitative Risk Assessment

Potential Source/Medium	*Potential Exposure Route*	*Potential Receptor*	*Severity*	*Probability*	*Risk Rating*
Made Ground associated with re-profiling of site levels	Ingestion, inhalation, dermal contact	Future site occupants	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Off-site residents	Medium	Low likelihood	Moderate / Low
	Direct contact	Buildings and infrastructure	Medium	Low likelihood	Moderate / Low
	Lateral and vertical migration	Groundwater (Secondary A Aquifer)	Medium	Low likelihood	Moderate / Low
		Surface Waters	Mild	Low likelihood	Low
	Ground gas migration	Buildings and infrastructure	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Future site occupants	Medium	Low likelihood	Moderate / Low
	Root uptake	Plants and vegetation	Minor	Low likelihood	Very low
Infilled Quarry (infilled materials)	Ingestion, inhalation, dermal contact	Future site occupants	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Off-site residents	Medium	Low likelihood	Moderate / Low
	Direct contact	Buildings and infrastructure	Mild	Low likelihood	Low
	Lateral and vertical migration	Groundwater (Secondary A Aquifer)	Medium	Low likelihood	Moderate / Low
		Surface Waters	Mild	Low likelihood	Low
	Ground gas migration	Buildings and infrastructure	Medium	Low likelihood	Moderate / Low
		Construction workers	Medium	Low likelihood	Moderate / Low
		Future site occupants	Medium	Low likelihood	Moderate / Low
	Root uptake	Plants and vegetation	Minor	Low likelihood	Very low

[31] https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm
[32] CIRIA. 2001. *Contaminated Land Risk Assessment. A guide to good practice*. C552.

7. GEOENVIRONMENTAL RECOMMENDATIONS

7.1 General

The proposed development is to comprise the construction of a new hotel together with associated parking, water park, landscaping and infrastructure. The recommendations are based on the scenario of a '*commercial*' end use. An assessment of the material classification has also been undertaken so that appropriate materials management can be implemented during the groundworks.

If, during the development of the site, materials are encountered that are not consistent with the findings of this investigation, then the adoption of further inspection and possible testing should be undertaken by a suitably qualified geoenvironmental engineer, to determine an appropriate course of action.

The following initial remedial works are recommended, based on the findings of the investigation. Recommendations are provided below with respect to good practice management of materials and health and safety.

7.2 Contamination and Remediation

Within the areas investigated, Made Ground was not encountered, and visual/olfactory evidence of potential contamination was not encountered. However, it should be noted that areas of the site (including areas of raised/mounded ground and the area of the historically infilled quarry) have not been investigated and, therefore, there is the potential for Made Ground to exist at the site that has not been encountered as part of the investigation.

On this basis, when access is available, it is recommended that further investigation is undertaken within areas not investigated as part of the recent investigation works, including areas of raised ground/mounds and the historical quarry.

If materials are encountered that are not consistent with the findings of this investigation, further inspection and possible testing should be undertaken by a suitably qualified geo-environmental engineer.

7.3 Material Management

Should soil be required to be disposed offsite, the chemical results have been used to classify soils for waste disposal based on guidance contained within WM3[33]. The chemical analysis results indicate that

[33] Environment Agency. 2015. *Waste Classification - Guidance on the classification and assessment of waste* (WM3)

the samples tested are classified as 'not hazardous' in accordance with WM3. The natural soils are likely to be classified as 'inert' based on their natural derivation.

During excavation of surplus material, the natural soils could be offered for re-use via the CL:AIRE register of material. The material will require transporting in accordance with the Environmental Protection (Duty of Care) Regulations, 1990. CGL is able to help with this and submit a Materials Management Plan (MMP) if required and provide guidance on the best code of practice for such activities.

7.4 Buried Services

Based on the findings of the chemical analysis, it is considered that special precautions with regards to potable water supply pipes (such as barrier pipe) are not likely to be required. The local Water Authority should be consulted and this report, including the appendices, plus the results of any additional investigations and assessment should be submitted for review to determine their site-specific requirements.

7.5 Health and Safety

Construction workers have the potential to come into contact with dusts and soils during the course of their activities. Based on the findings of the investigation the risk to construction workers is assessed as moderate. Therefore, appropriate health and safety measures should be incorporated during construction. Such precautions should include, but not be limited to:

1. Personal hygiene, washing and changing procedures.
2. Personal protective equipment, including disposable overalls, gloves etc.
3. Measures to avoid surface water ponding and positive collection and disposal of all on-site run-offs.
4. Regular cleaning of all site roads and access roads including dust suppression methods (e.g. water spraying), if necessary.

Off-site residents could also be affected by dust generated. However, it is anticipated that appropriate dust suppression will be implemented as part of the works.

7.6 Watching Brief and Discovery Strategy

It is recommended that a watching brief is maintained by the Principal Contractor during groundworks. In the event unexpected, infilled ground or gross contamination, such as oily material or material of an unusual colour or odour, is encountered, the following discovery strategy is recommended:

1. Works to cease in that area;

2. The main works contractor is to notify a suitably qualified geoenvironmental engineer, to attend site and sample the material for appropriate analysis and risk assessment. Dependent on the recommendations of the engineer, it may be necessary to notify Contaminated Land Officers of the Local Authority and the Environment Agency, as appropriate;
3. If required by the risk assessment, a geoenvironmental engineer shall supervise the excavation/removal of contaminated material. Contaminated soils should be placed in a bunded area and covered to prevent rainwater infiltration. To facilitate appropriate waste disposal and potential re-use of materials all excavated soils should be segregated and stockpiled depending on their soil classification;
4. Soil samples should be obtained by the geoenvironmental engineer from both the excavated material, and the soils in the sides and base of the excavation to demonstrate that the full area of contamination has been excavated. Where appropriate, in-situ testing should be undertaken on the sides and base of the excavation to assess the presence of residual contamination in the soils;
5. On receipt of chemical test results, the soils may be classified for disposal, or treatment if appropriate, and dealt with accordingly;
6. Detailed records of the stockpile sizes, source and location should be kept and regularly updated to allow materials to be easily tracked from excavation until leaving the site.

Records of excavated areas and the results of chemical testing should be incorporated within the final verification report for the site.

8. GEOTECHNICAL RECOMMENDATIONS

8.1 General

The following recommendations are based on the ground conditions encountered during the investigation works and the results of subsequent geotechnical testing. The soil descriptions and geotechnical laboratory data have been interpreted to provide recommendations the proposed development, understood to comprise the construction of a new hotel together with associated parking, water park, landscaping and infrastructure. Should the end use be different, then it may be necessary to review the findings and recommendations to ensure that they are appropriate for the development.

At the time of production of this Draft report (December 2021), certain laboratory tests have not been made available. On completion, this report will be included with results of laboratory testing included. Subject to the results of laboratory testing, the parameters given in Table 16 may be amended.

8.2 Geotechnical Design Parameters

Geotechnical design parameters have been derived for the encountered strata based on the soil descriptions, laboratory testing results and in-situ testing, supplemented with published data and CGL's experience with similar geological strata. A summary of the design parameters is presented in Table 16 below.

Table 16. Summary of Geotechnical Design Parameters

Stratum	Design Level (mbgl) [m AOD]	Bulk Unit Weight γ_b (kN/m^3)	Undrained Cohesion c_u (kPa)	Effective cohesion c' (kPa)	Friction Angle ϕ' (°)	UCS (MPa)
Cornbrash – residual soils (granular)	0.10 – 0.40 [84.65 – 80.39]	19 [a]	-	0	33[d,e]	-
Cornbrash – residual soils (cohesive)		19 [a]	40 [c]	0	24[e]	-
Cornbrash – limestone	1.35 – 2.10 [83.41 – 78.59]	24 [b]	-	5	37	10[f]
Cornbrash – marl	1.90 – 2.10 [82.82 – 81.23]	22 [a]	-	2	33	2[f]
Forest Marble – cohesive	2.00 – 3.05 [82.83 – 78.59]	20 [a]	60 [b]	2	24[e]	-
Forest Marble – mudstone	1.95 – 2.20 [81.79 – 79.11]	22 [a]	-	1	33	1[f]
Forest Marble – limestone	2.70 – 7.25 [81.83 – 75.05]	24 [b]	-	5	37	15[f]

Notes

a. Assumed value based on strata descriptions and BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution
b. Laboratory testing
c. In-situ testing
d. Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.
e. BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution.
f. UCS values are conservative values adopted for foundation design, which cautiously takes into consideration the presence and potential or fractured/weakened zones. Actual results and average values are considered to be much greater and, for excavatability purposes, an average mean UCS of 26MPa has been adopted (based on results of testing undertaken).

Based on the monitoring undertaken, a design groundwater level of between 78.28 m AOD to 83.63mOD is recommended at this stage. this should be reviewed following completion of additional monitoring (including recovery of data from groundwater monitoring divers).

Perched water may also be encountered at variable levels within the limestone and shallow residual soils. It should be noted that groundwater and perched water are likely to be subject to seasonal variations and further monitoring may be required at further stages prior to construction of the proposed development.

8.3 Foundations

Based on the anticipated loadings of the proposed structure, shallow spread foundations (including strip/trench fill and/or pad foundations) are likely to be appropriate to support the proposed structure. An allowable bearing pressure of 300kN/m^2 is considered to be appropriate for foundations founded within limestones/marls of the Cornbrash Formation or cohesive deposits/mudstones/limestones of the Forest Marble Formation.

Dewatering and water control is likely to be required where foundations extend into/below the water table. Perched water may, however, still be present within shallow excavations where constructed above recorded water levels (which may still also require localised dewatering).

Where foundations span two soil types (including between weathered soils and rock and fractured/ brecciated limestone and intact limestone), consideration should be given to reinforcement to mitigate the effects of potential differential settlement (particularly if between residual soil and intact limestone).

8.4 Basement Construction

Based on the recorded ground and groundwater conditions, excavation support and dewatering are likely to be required during construction the proposed basement. Excavation to formation level of the basement will include excavation through the shallow residual soils into the underlying limestones, clays, marls and mudstones of the Cornbrash Formation and Forest Marble Formation.

Rising head permeability tests were undertaken within boreholes BH04 and BH07 during the monitoring visit on the 8th February. The results indicate that a relatively fast water inflow may be encountered in excavations and, therefore, water control will be required in excavations that encounter groundwater.

The proposed basement is likely to be constructed by use of a secant piled wall or contiguous piled wall in order to restrict water flow in the short and long-term.

8.5 Excavatability

An assessment of the excavatability has been evaluated with reference to the Pettifer and Fookes[34] (P&F)/Waltham[35] excavatability graph, modified by Berkay Kentli & Tamer Topal[36], which presents a simplified graphical method of determining excavation methods based on a correlation between UCS data/rock strength and rock fracture spacing. The assessment uses BS5930:1981, therefore a correlation with the current BS5930:2020 has been completed and presented in Table 17, below.

Table 17. Correlation of BS5930:1981 and BS5930:2020.

BS5390:1981		BS5930:2020		BS5930:1981 and 2020	
Strength Term	**UCS (MPa)**	**Strength Term**	**UCS (MPa)**	**Discontinuity term**	**Spacing**
Very Weak	0.6 to 1.25	Extremely Weak	<1.0	Very Small	<60
Weak	1.25 to 5.0	Very Weak	1.0 to 5.0	Small	60 to 200
Moderately Weak	5.0 to 12.5	Weak	5.0 to 25	Medium	200 to 600
Moderately Strong	12.5 to 50	Medium Strong	25 to 50	Large	600 to 2000
Strong	50 to 100	Strong	50 to 100	Very Large	>2000
Very Strong	>100	Very Strong	100 to 250	-	-

The zones defining excavation methods denoted on the P&F excavatability graph describe the ease at which the material can be excavated according to the following descriptions[35]:

- **Easy Digging** – possible in fractured rock of mass and is soils, using face shovel, backhoe, clam shell grab or dragline;
- **Ripping** – needed to break up slightly stronger rock, using tractor-mounted ripper or breaking with boom mounted hydraulic pecker; and
- **Blasting** – generally required in stronger and less fractured rock.

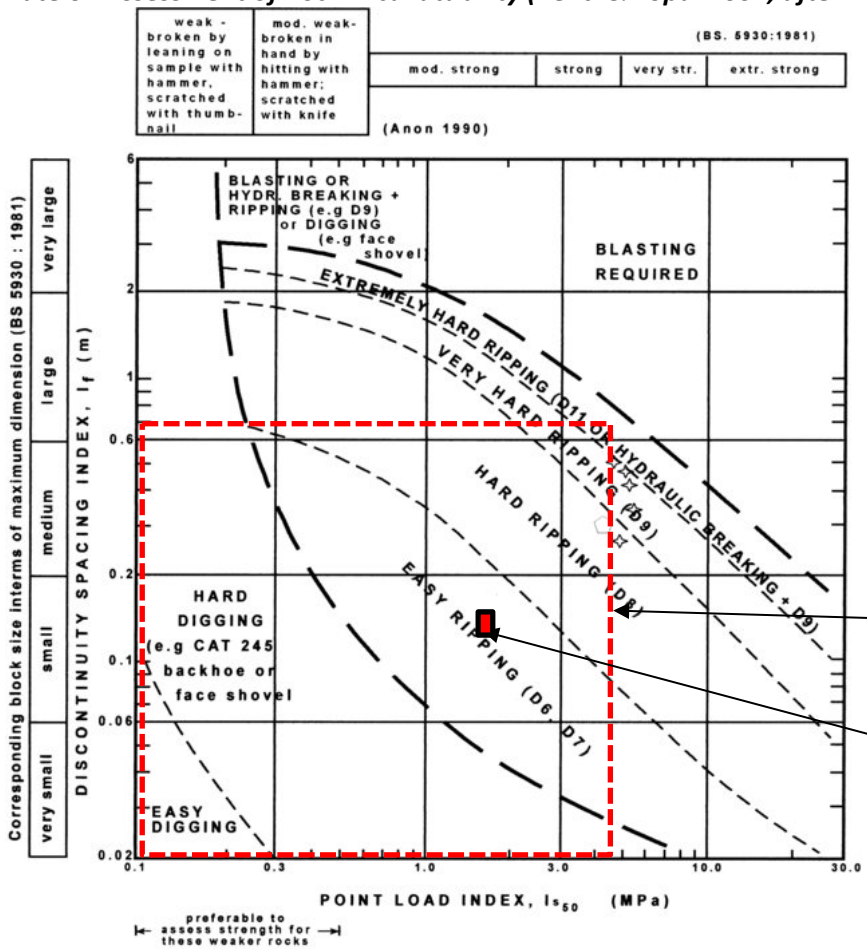
The assessment below has been based on fracture spacing and point load testing of rock samples. Based on the drawings provided in Appendix A, the assessment below has considered rock samples up to 6m depth only (considered to be the maximum required excavation depth). Should deeper depths be excavated, this assessment should be revised.

[34] Pettifer G.S. and Fookes, P.G (1994) *A revision of the graphical method for assessing the excavatability of rock*. Q J Eng Geol. 145- 164

[35] Waltham, T. (2009). Foundations of Engineering Geology. 3rd Edition.

[36] Berkay Kentli & Tamer Topal (July 2004). Evaluation of rock excavatability and slope stability along a segment of motorway, Pozanti, Turkey. Environmental Geology 46(1):83-95

Plate 6. Assessment of Rock Excavatability (Kenti & Topal 2004, after Peter & Fookes 1994)



Range	Min	Max	Mean
Spacing (m)	0.01	0.65	0.15
IS_{50} (MPa)	0.03	4.69	1.30
UCS (MPa)	0.175	98.49	26.2

Indicators based on rock strength and fracture spacing

Mean

The above assessment has been based on the data available during the investigation phase of the works and the rocks encountered are characterised as being between easy digging to extremely hard ripping (or hydraulic breaking), with an average classification of easy ripping. It should be noted that the above assessment referenced within the P&F methodology assumes excavations to be undertaken using a CAT245 excavator (60t).

The presence of fractured zones may be encountered resulting in “blocky” limestones locally being present. Such features may result in less onerous excavatability.

Shallow excavations may typically remain stable in the short term. However, instability should be anticipated in excavations left open for extended periods of time. No operatives should enter unshored or otherwise unprotected excavations in accordance with the guidelines presented in CIRIA report 97[37].

Where service excavations go deeper into the underlying rocks, overbreak should be anticipated.

[37] CIRIA (1992). *Trenching Practice (Second Edition).* Construction Industry Research and Information Association Report 97.

Early discussions with an appropriately experienced groundworks contractor are recommended to establish a reasonable estimate on the costs of this excavation and programme implications.

8.6 Cuttings and Retaining Walls

On the basis of the findings of the investigation, it is recommended that temporary and permanent cuttings at the site are undertaken in accordance with the principles of the observational method as set out in CIRIA guidance reports[38] and in Eurocode 7[39]. A 'traffic light' system can then be determined for the rock cuttings during the construction phase.

8.7 Floor Slabs

Based on the ground conditions encountered, ground floor slabs are recommended where placed in areas of granular soils. In areas of cohesive soils, consideration should be given to the use of a suspended floor slab.

8.1 Buried Concrete

Chemical analysis was undertaken in accordance with BRE SD1 to determine concrete classifications of the soil. The Jurassic strata beneath the site are potentially pyritic, and on this basis, the percentage of oxidisable sulfate has been calculated. The results indicate oxidisable sulfate above 0.3% in six out of 18 samples of the natural soils (specifically, six out of eight samples of clay/mudstone) and the total potential sulfate (TPS) has therefore been considered in the selection of design sulfate class.

The availability of total potential sulfate (TPS) in pyritic soils is dependent on the extent to which soils are disturbed, and the level to which the soils may oxidise, resulting in sulfate ions that may reach the concrete. On this basis, the appropriate DS and ACEC class for the pyritic soils, i.e. based on water soluble sulfate or total potential sulfate, should be adopted dependant on the extent to which the soils will be disturbed during construction. On this basis a Design Sulphate class DS-5, AC5 would apply for buried concrete.

8.2 Road / Pavement Design

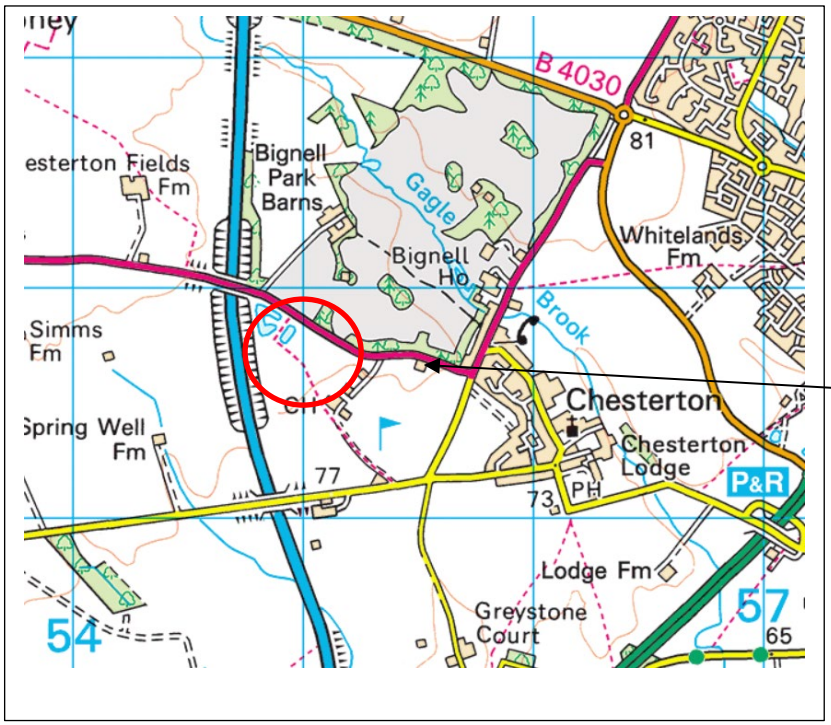
In accordance with CD225[40] it is recommended that where cohesive, residual Cornbrash Formation soils are present, a CBR value of 3% is recommended. For granular Cornbrash Formation strata (residual soil) is recorded a CBR value of 30% is considered appropriate. Where limestone is present, a

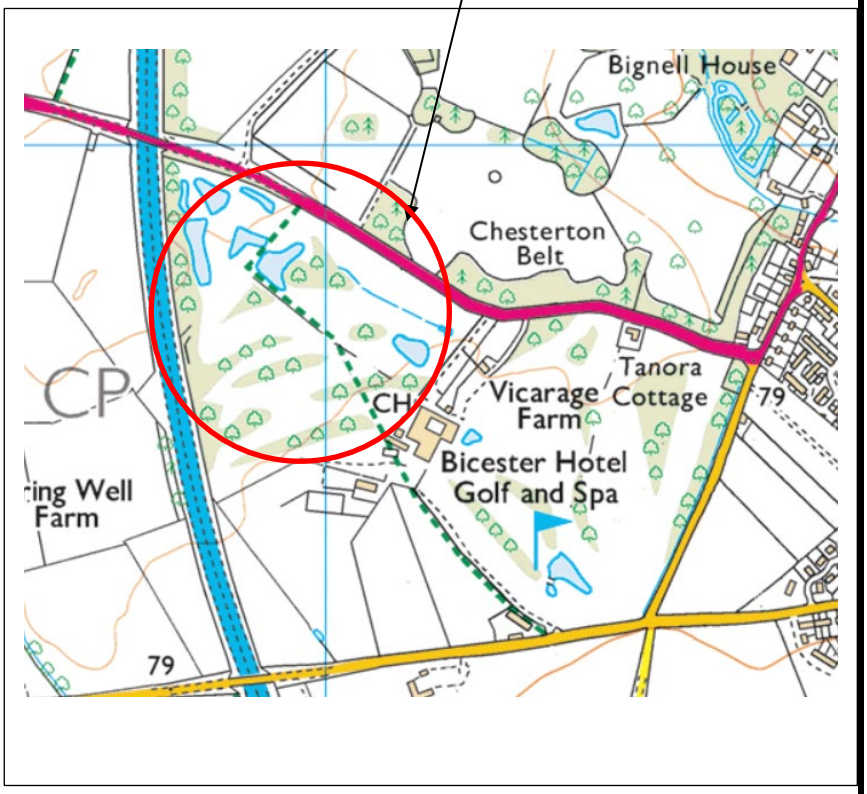
[38] Nicholson, D, Tse, Ch-Ming, Penny, Charles (1999) *The Observational Method in ground engineering: principles and applications*, CIRIA Report 185.
[39] BS-EN 1997-1 (2004) *Eurocode 7: Geotechnical design – part 1 general rules,* British Standards Institution, 2004
[40] Highways England. (2020). Design for New Pavement Foundations. CD225.

CBR value of >50% is recommended. Where Made Ground is encountered at formation level than a CBR value of 2% is recommended.

During construction, the sub-grade formation layer shall be proof rolled prior to placement of the first layer of engineered fill material with any soft spots or loose area identified during the proof roll removed and replaced with Engineered Fill. Any soft and/or compressible deposits identified in areas of proposed fill should be excavated and removed prior to the placement of Engineered fill. It is recommended that a suitably qualified geotechnical engineer inspects formation prior to the commencement of any backfill works.

FIGURES





Client	Project	Job No
Elliott Wood Partnership Limited	**Bicester Golf Club, Bicester, Oxfordshire**	**CG/39017**
CGL	Title: **Site Location Plan**	**Figure 1**

Photo 1. Photo showing typical rotary borehole rig setup

Photo 2. Photo showing greens/fairways marked by tree-lined boundaries

Photo 3. Photo showing greens/fairways marked by tree-lined boundaries, with sand bunkers

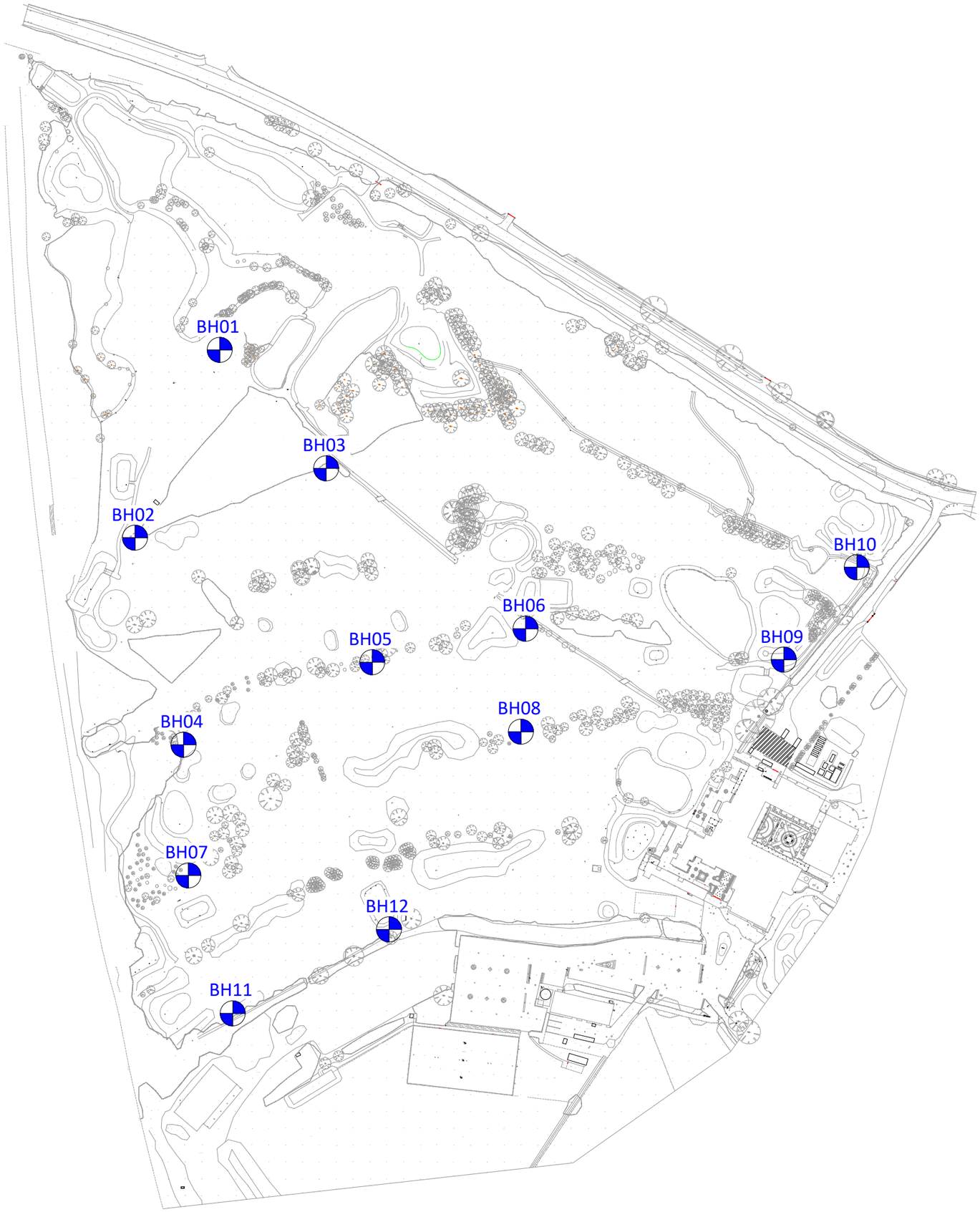
Photo 4. Photo showing greens areas of raised/mounded ground (reinstated borehole in foreground of photograph)

Photo 5. Photo showing greens/fairways marked by tree-lined boundaries

Photo 6. Photo showing greens/fairways and raised/mounded areas

Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Course, Bicester**	**CG/39017**
CGL	Title: **Photosheet**	**Figure 2**

N



KEY

Rotary Borehole

Notes

1. Do not scale from this drawing.
2. Topographical survey taken from 1st Horizon Surveying & Engineering Limited drawing 'CS-GW5389' (12/04/2019).
3. Proposed levels extracted from topographic survey.

Rev	Date	Comments
0	02/12/21	First issue

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Project
Bicester Golf Club, Bicester, Oxfordshire

Client
Elliott Wood Partnership Limited

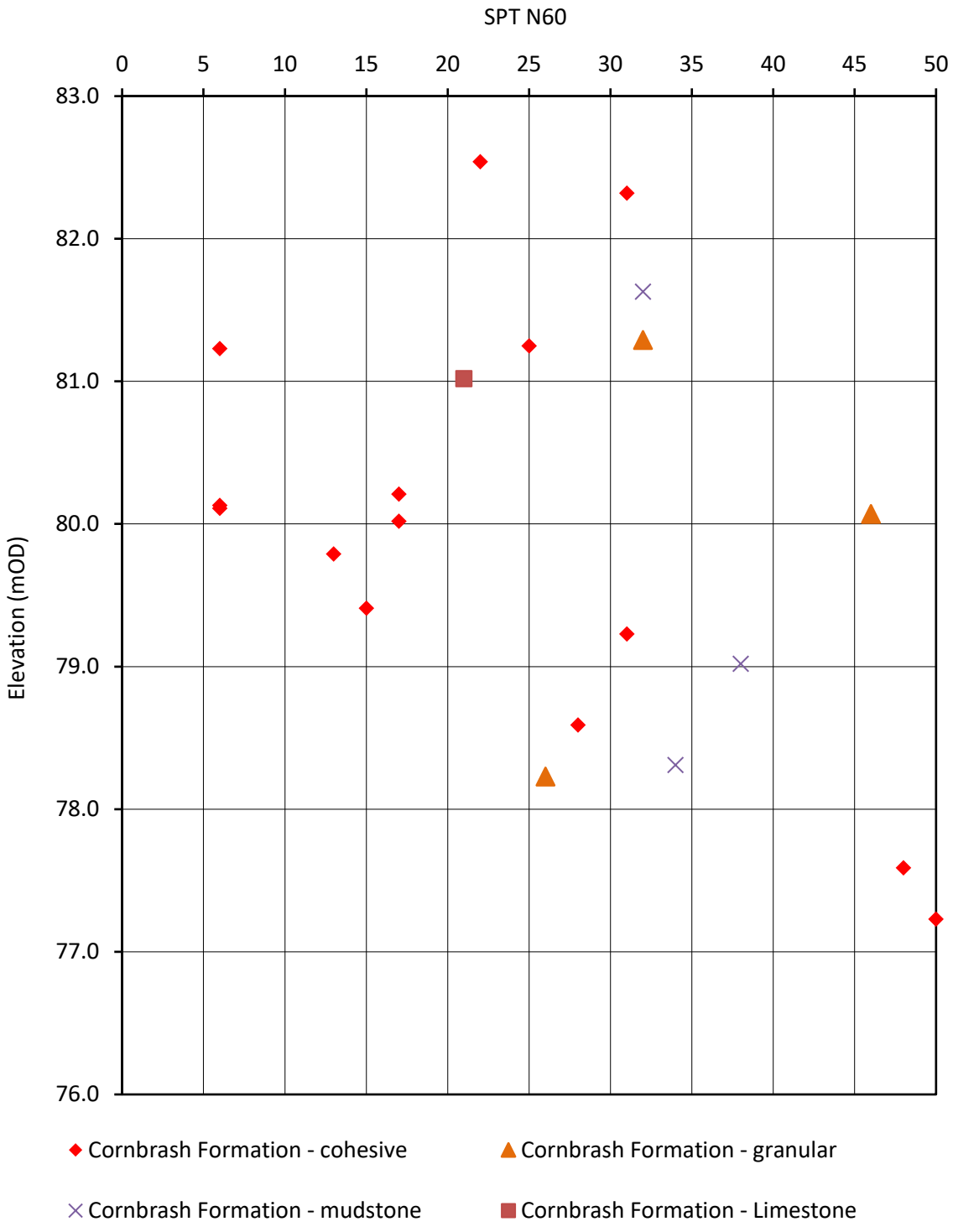
Drawing title
Exploratory Hole Location Plan

Scale(s)	Job No.
NTS	**CG/39017**

Drawn	ARA	02/12/21
Checked		
Approved		

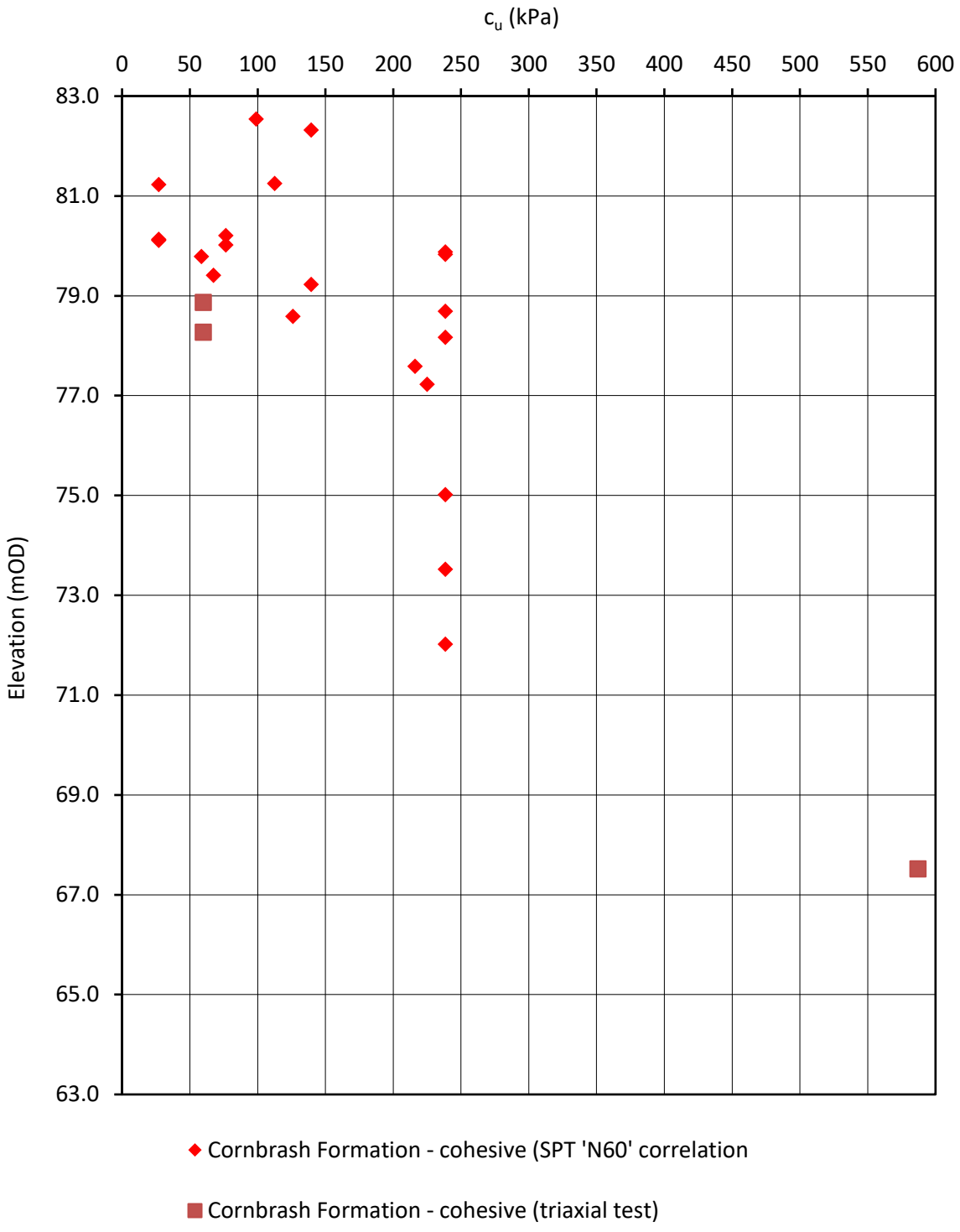
Dwg No. **Figure 3**

Rev. **0**



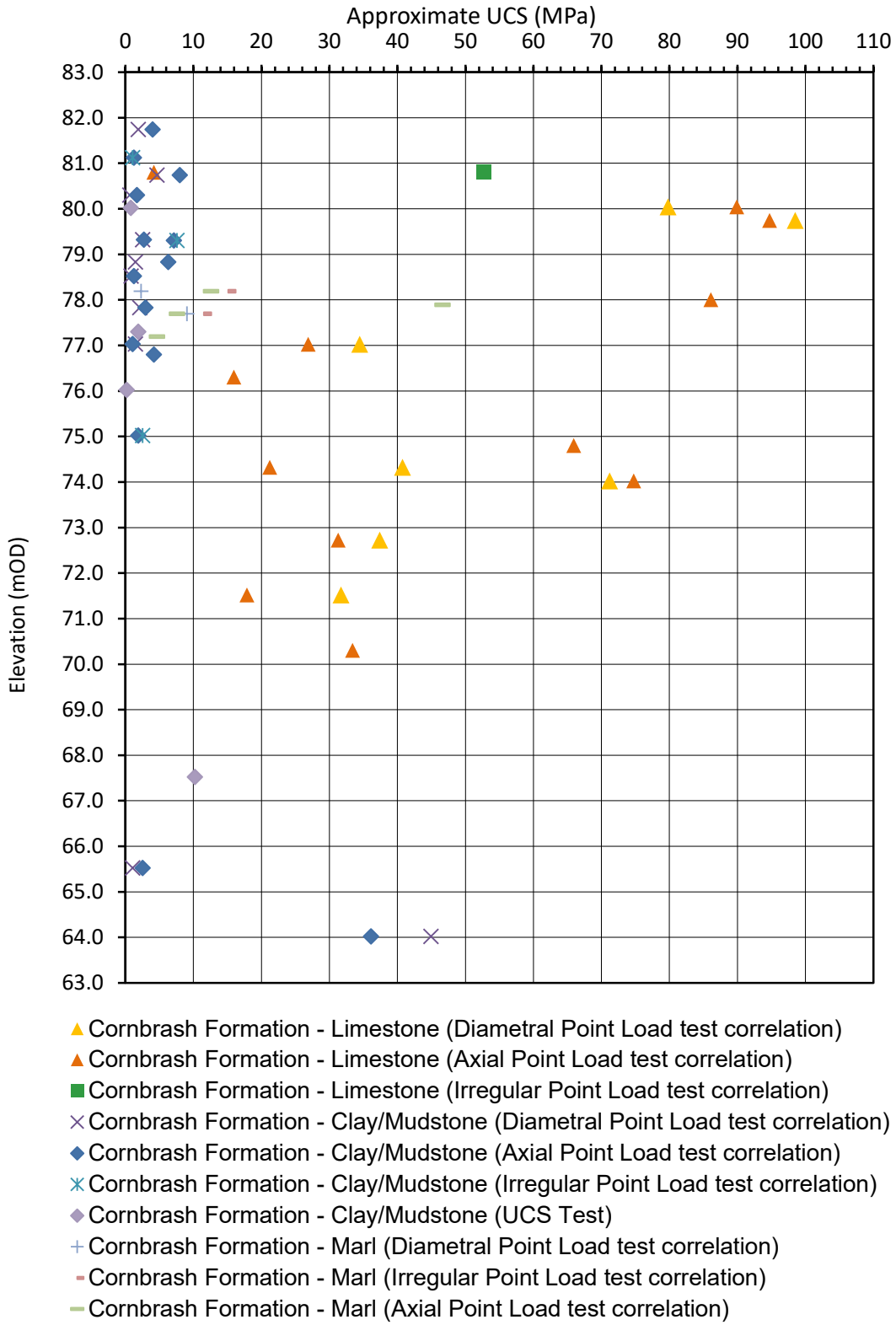
Note: Values are corrected N60 values (SPT hammer energy ratio of 64%)

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **SPT 'N' Value vs Level**	**Figure 4**



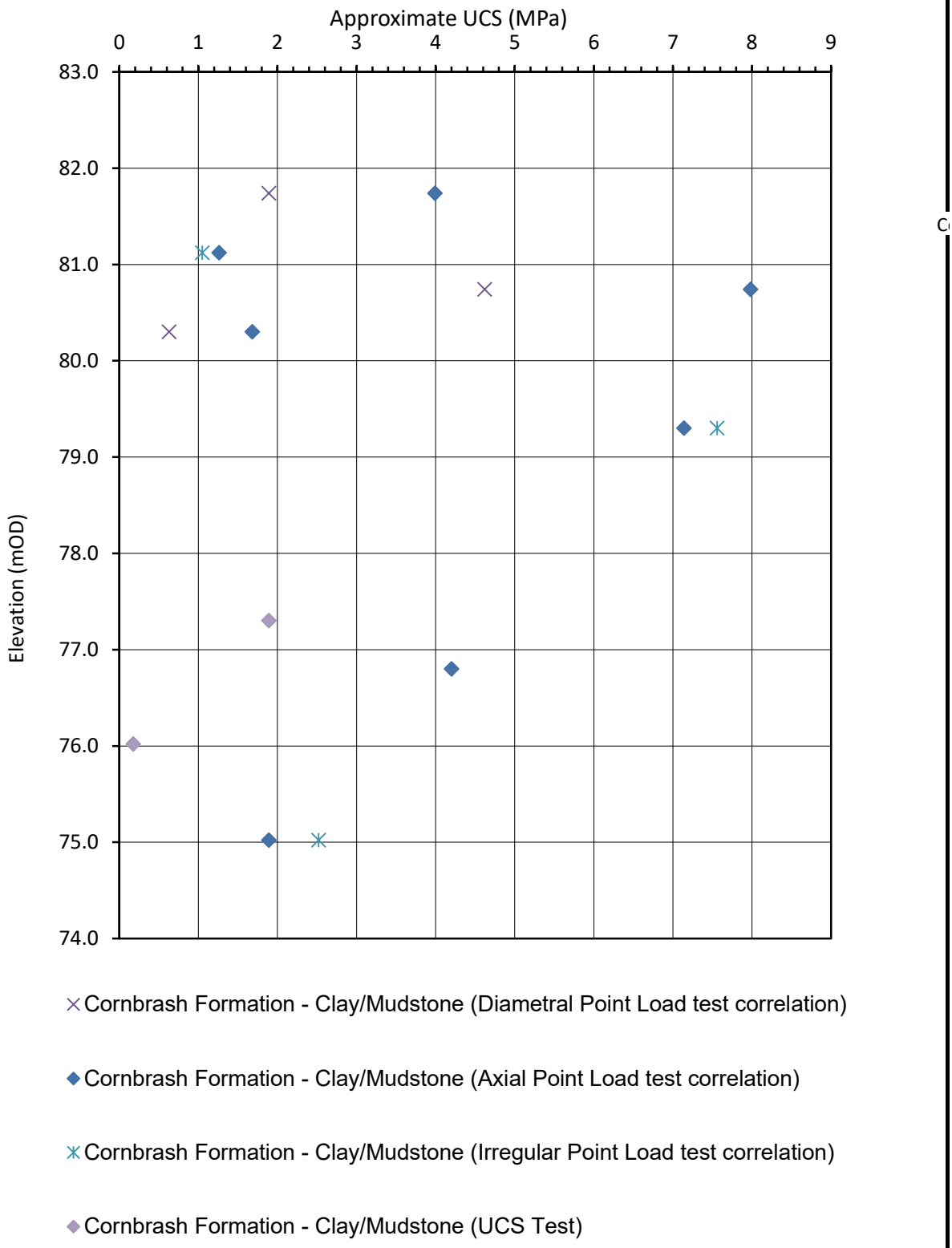
Note: Cu correlation based on 4.5xN60

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Undrained Shear Strength (Cu vs Level)**	**Figure 5**



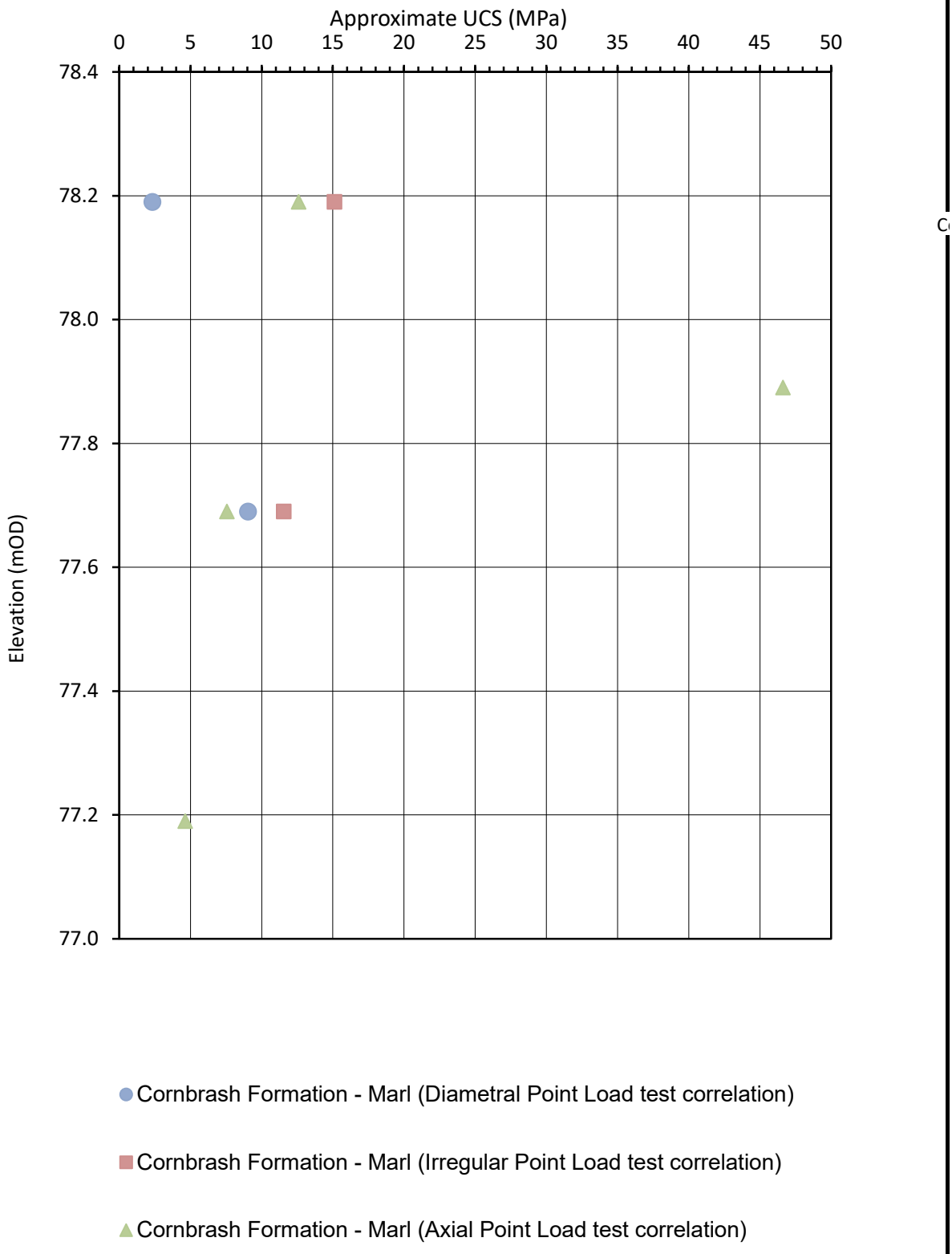
Note: Point load index $IS_{(50)}$ to approximate UCS based on correlation where approximate UCS = 21x $IS_{(50)}$

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **UCS vs Level - All Data**	**Figure 6**



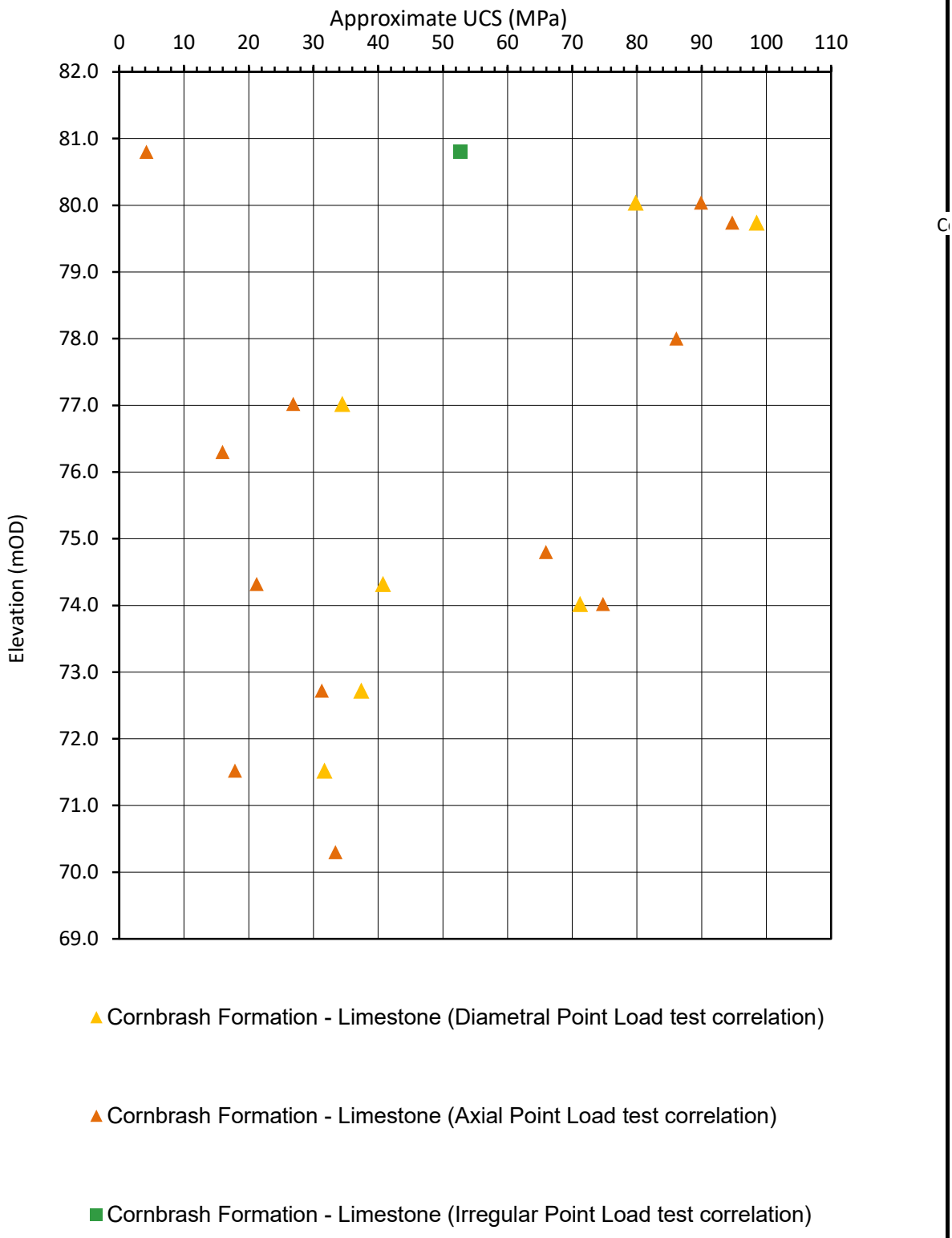
Note: Point load index $IS_{(50)}$ to approximate UCS based on correlation where approximate UCS = 21x $IS_{(50)}$

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **UCS vs Level - Clay/Mudstone**	**Figure 7**



Note: Point load index $IS_{(50)}$ to approximate UCS based on correlation where approximate UCS = 21x $IS_{(50)}$

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **UCS vs Level - Marl**	**Figure 8**

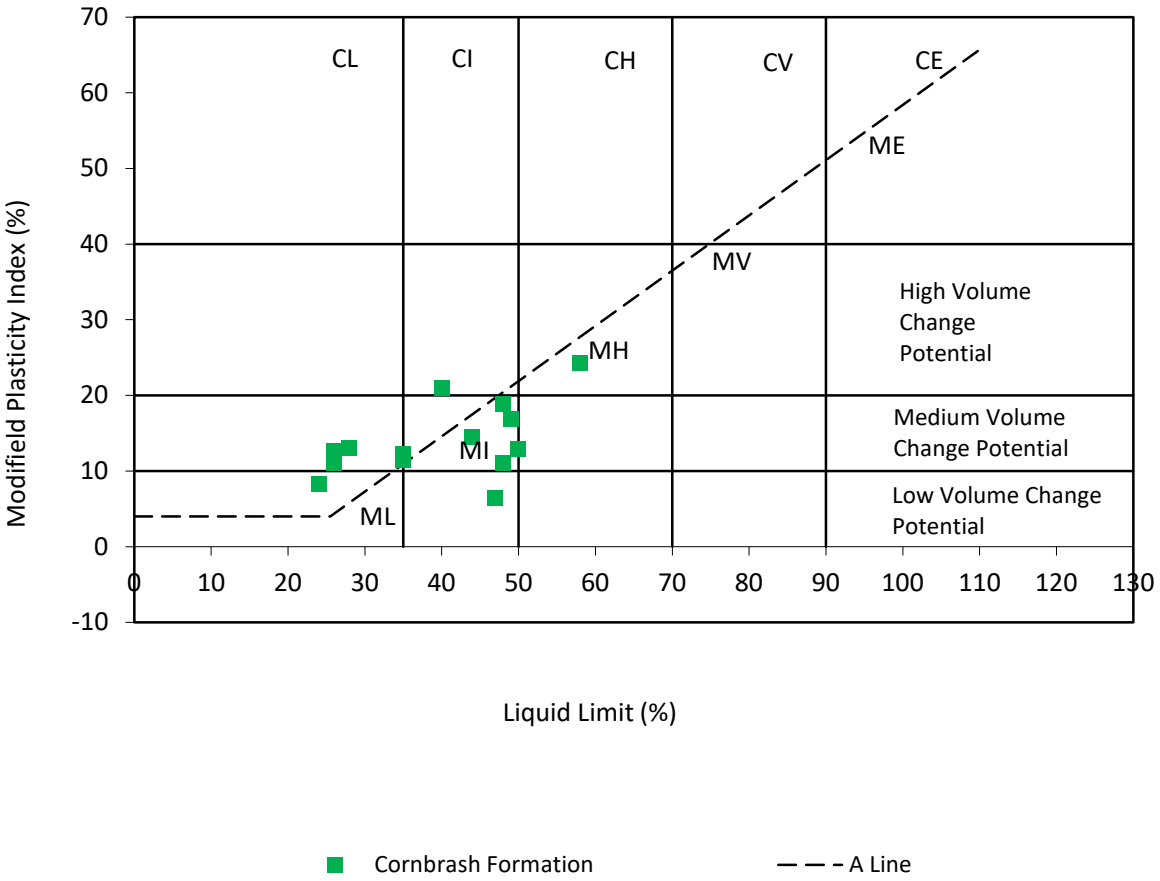


Note: Point load index $IS_{(50)}$ to approximate UCS based on correlation where approximate UCS = 21x $IS_{(50)}$

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **UCS vs Level - Limestone**	**Figure 9**

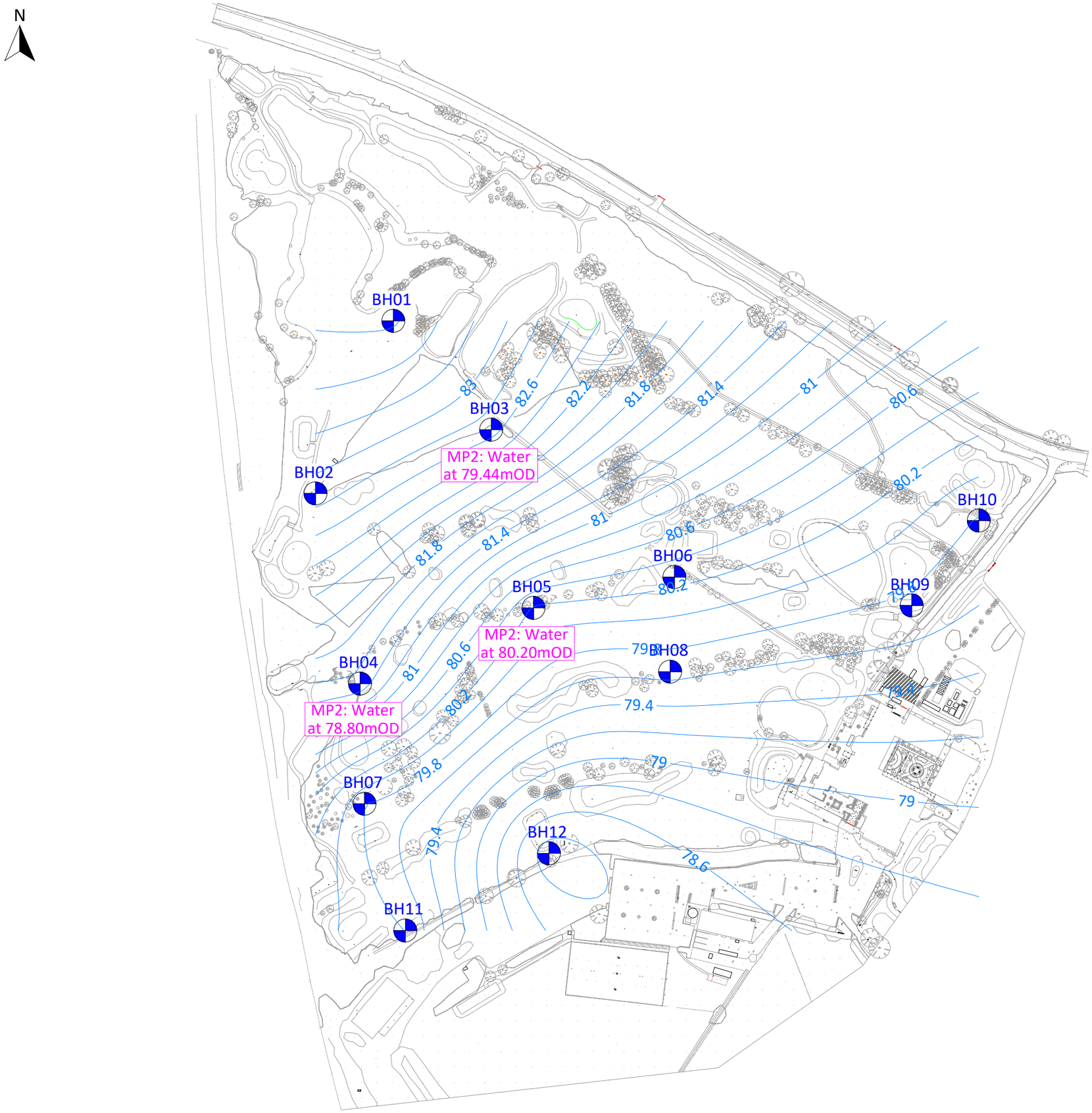
Key:
C Clay M Silt

L Low plasticity
I Intermediate plasticity
H High plasticity
V Very high plasticity
E Extremely high plasticity



Notes. Volume change potential based on NHBC 4.2 : 2016 : Building near trees. Plasticity of the soils is based on BS 5930 : 2015 : Code of practice for site investigations. British Standards Institution, London.

Client	Project	Job No.
Elliott Wood Partnership	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Plasticity Index Chart**	**Figure 10**



KEY

Rotary Borehole

Groundwater level (mOD)

Notes

1. Do not scale from this drawing.
2. Topographical survey taken from 1st Horizon Surveying & Engineering Limited drawing 'CS-GW5389' (12/04/2019).
3. Proposed levels extracted from topographic survey.

Rev	Date	Comments
0	17/11/2021	First issue

Card Geotechnics Ltd
4 Godalming Business Centre
Woolsack Way
Godalming
Surrey
GU7 1XW
T: 01483 310600

Project
Bicester Golf Club, Bicester, Oxfordshire

Client
Elliott Wood Partnership Limited

Drawing title
Groundwater Level Contour Plan

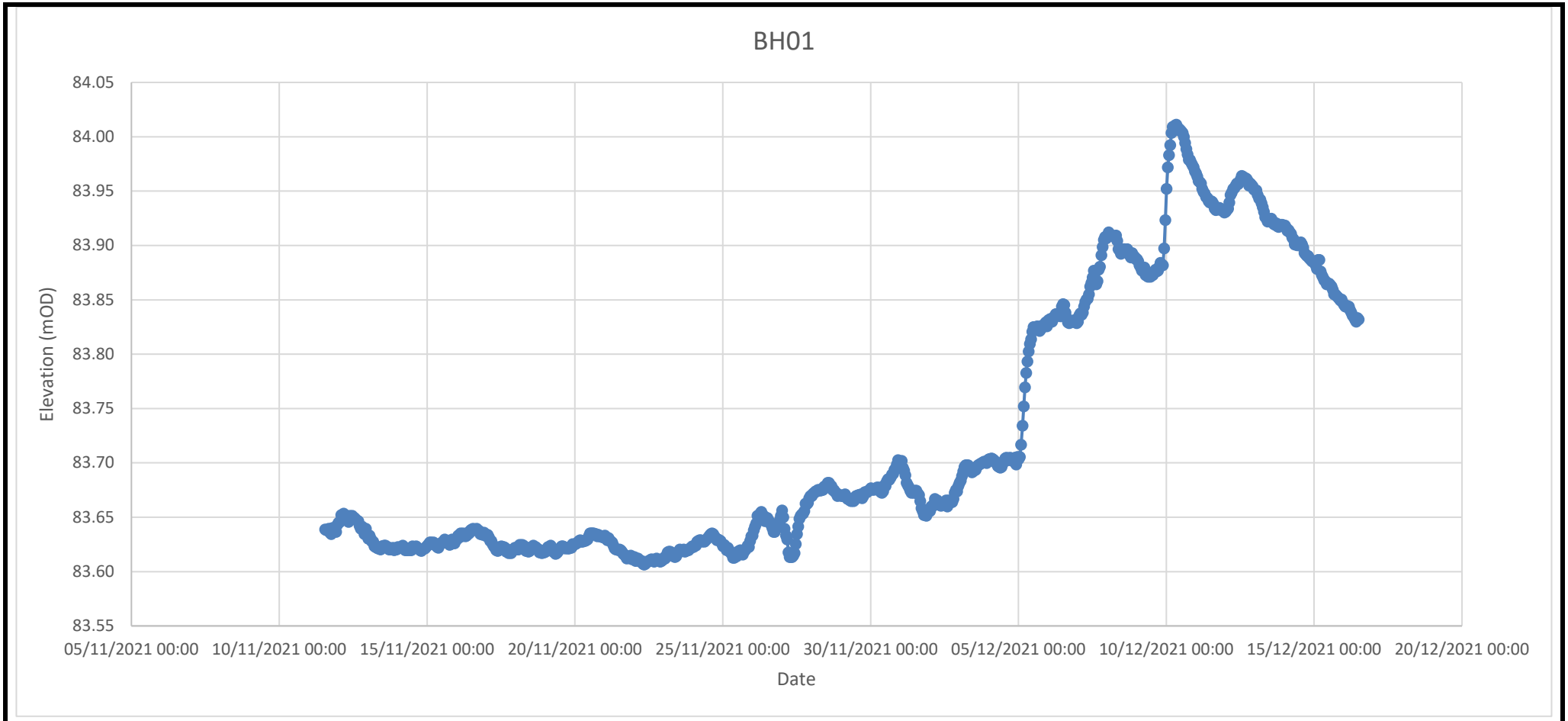
Scale(s)
NTS

Job No.
CG/39017

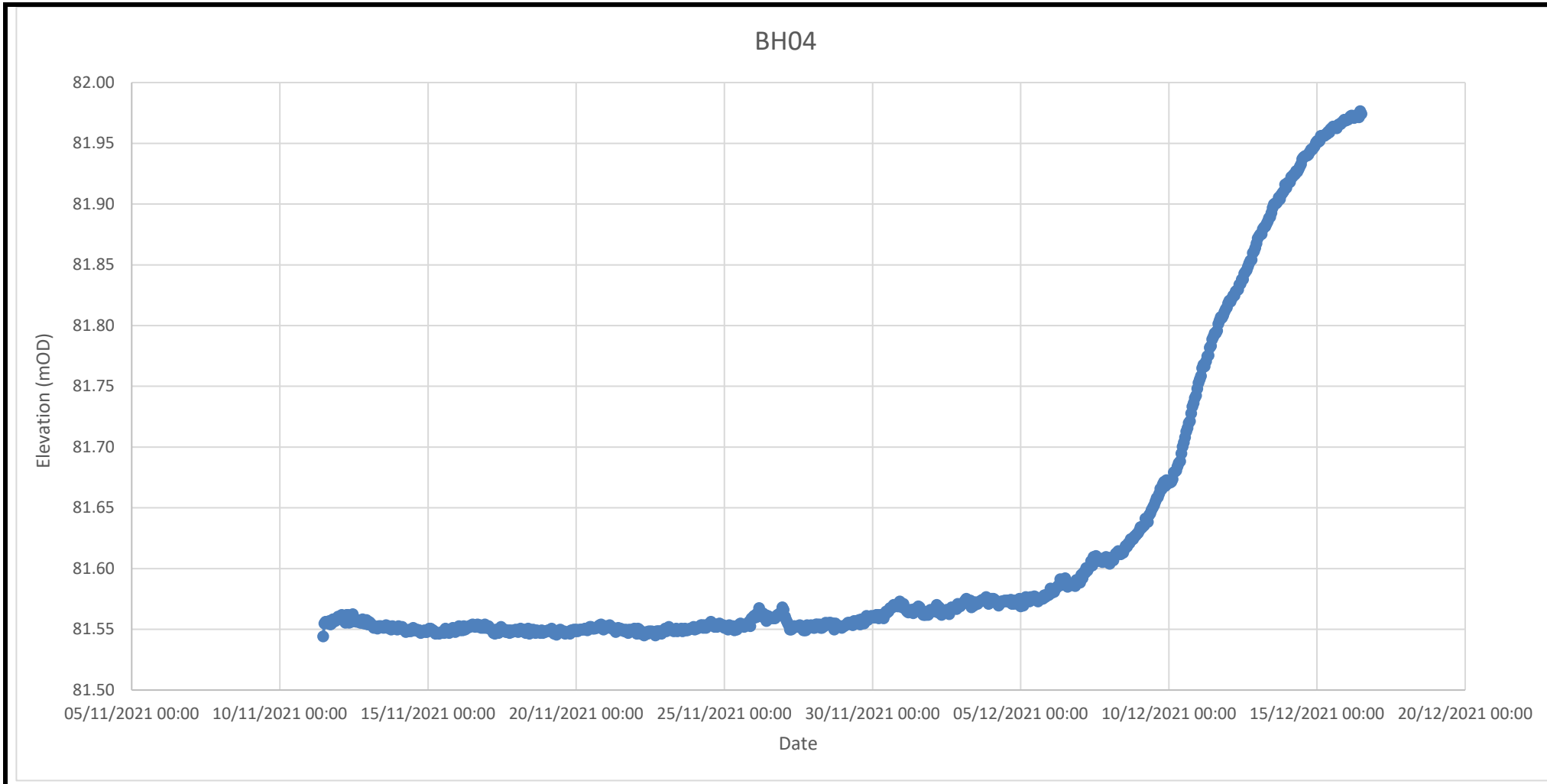
Drawn	TSB	07/10/2021
Checked		
Approved		

Dwg No.
Figure 11

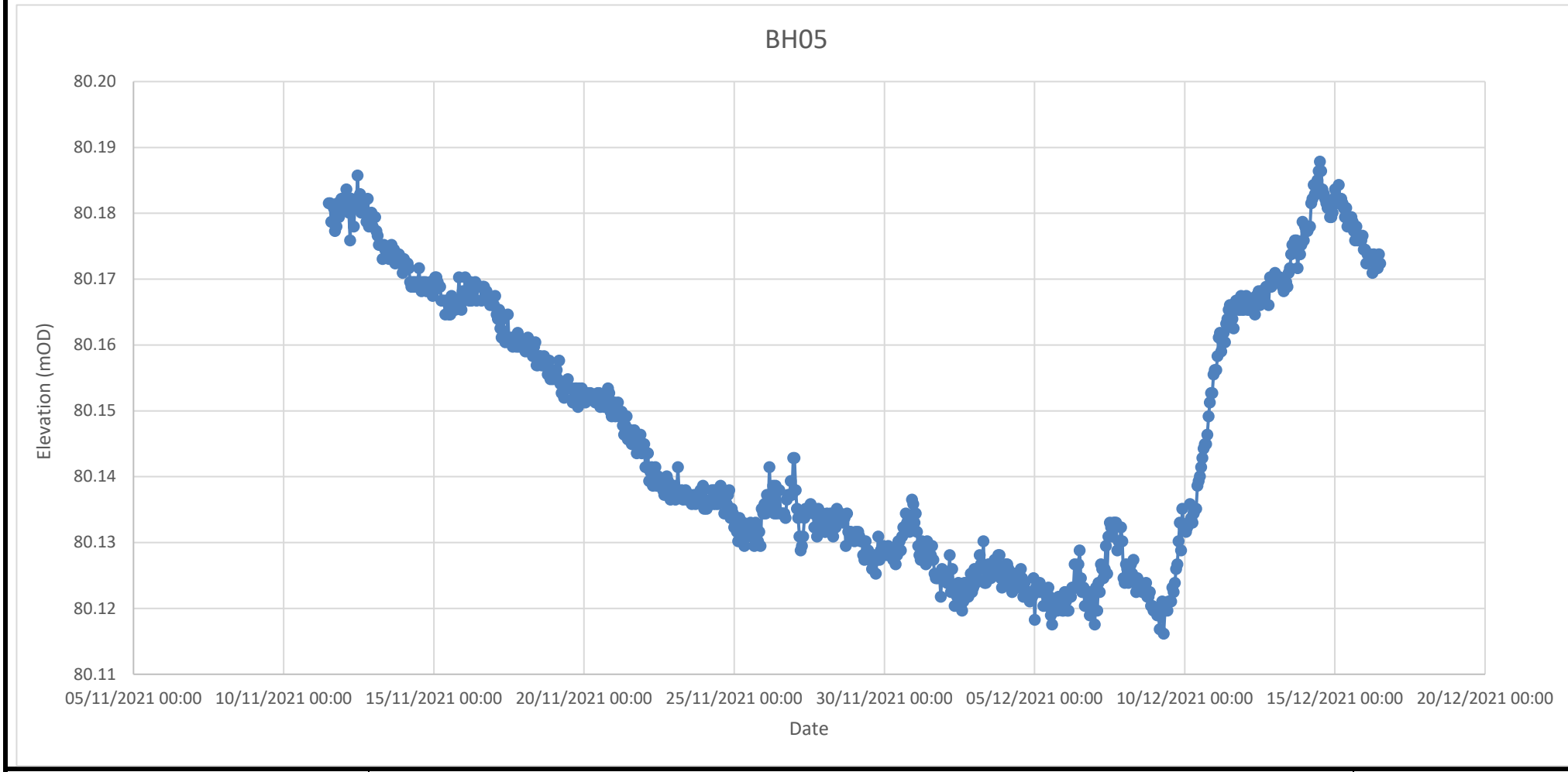
Rev.
0



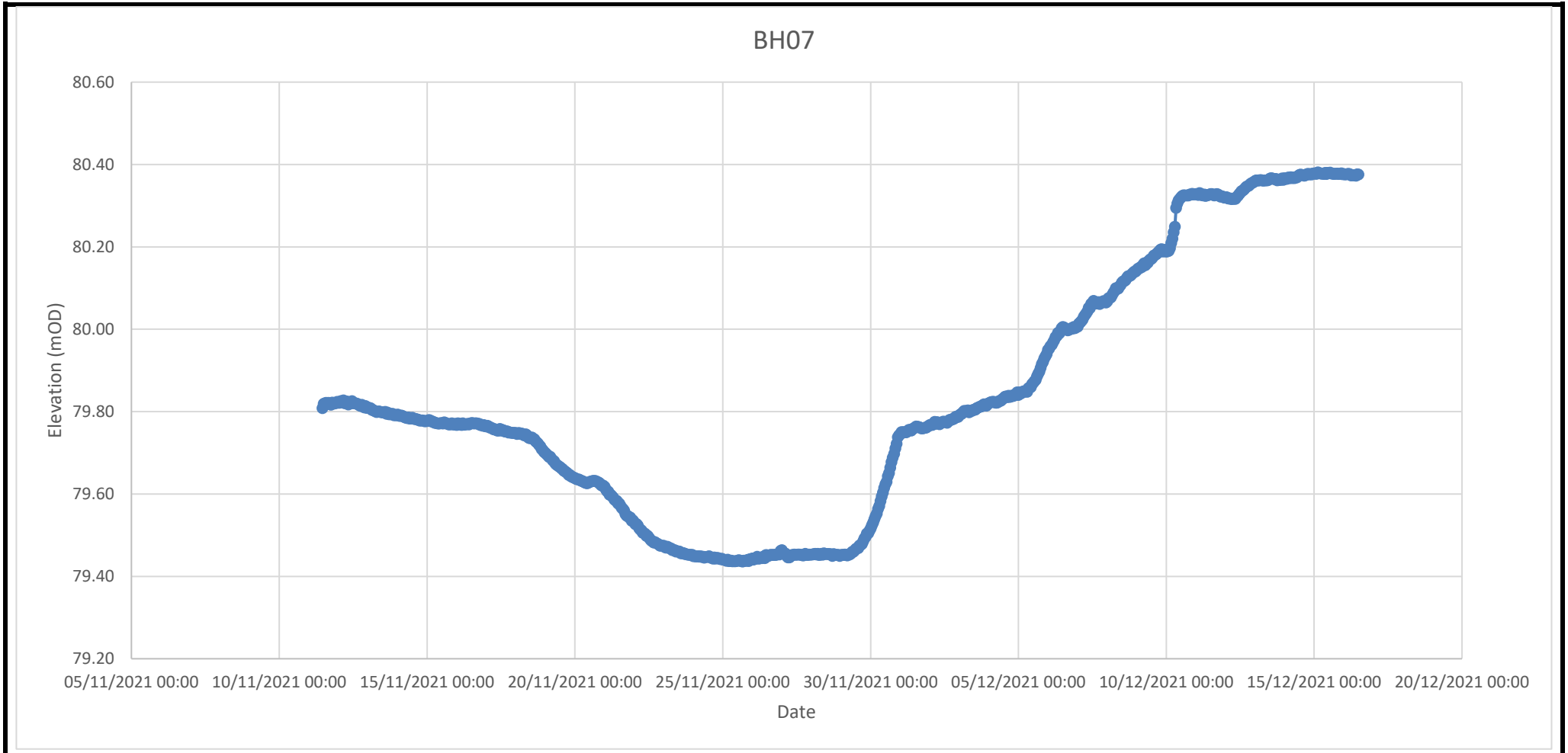
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



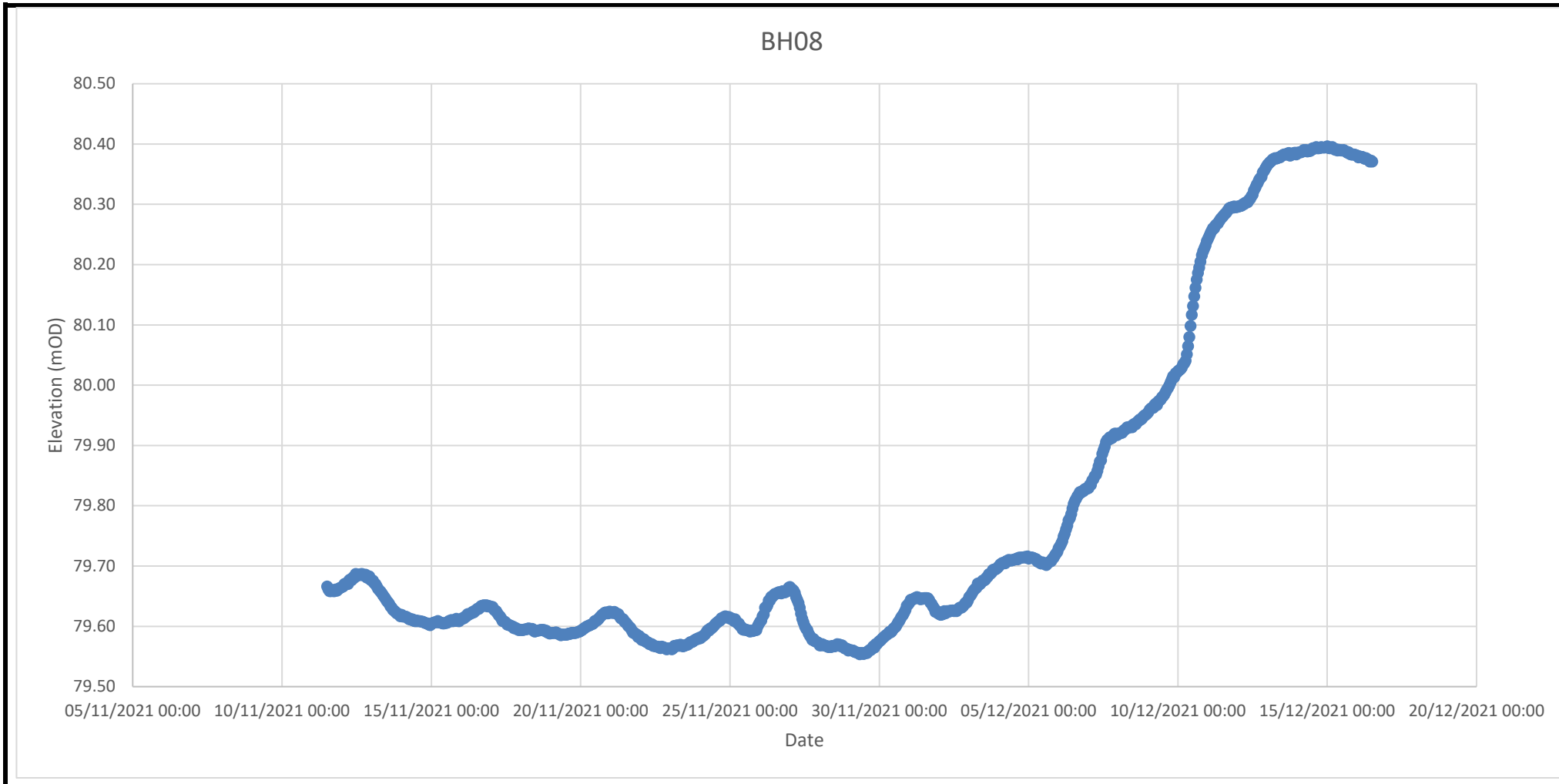
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



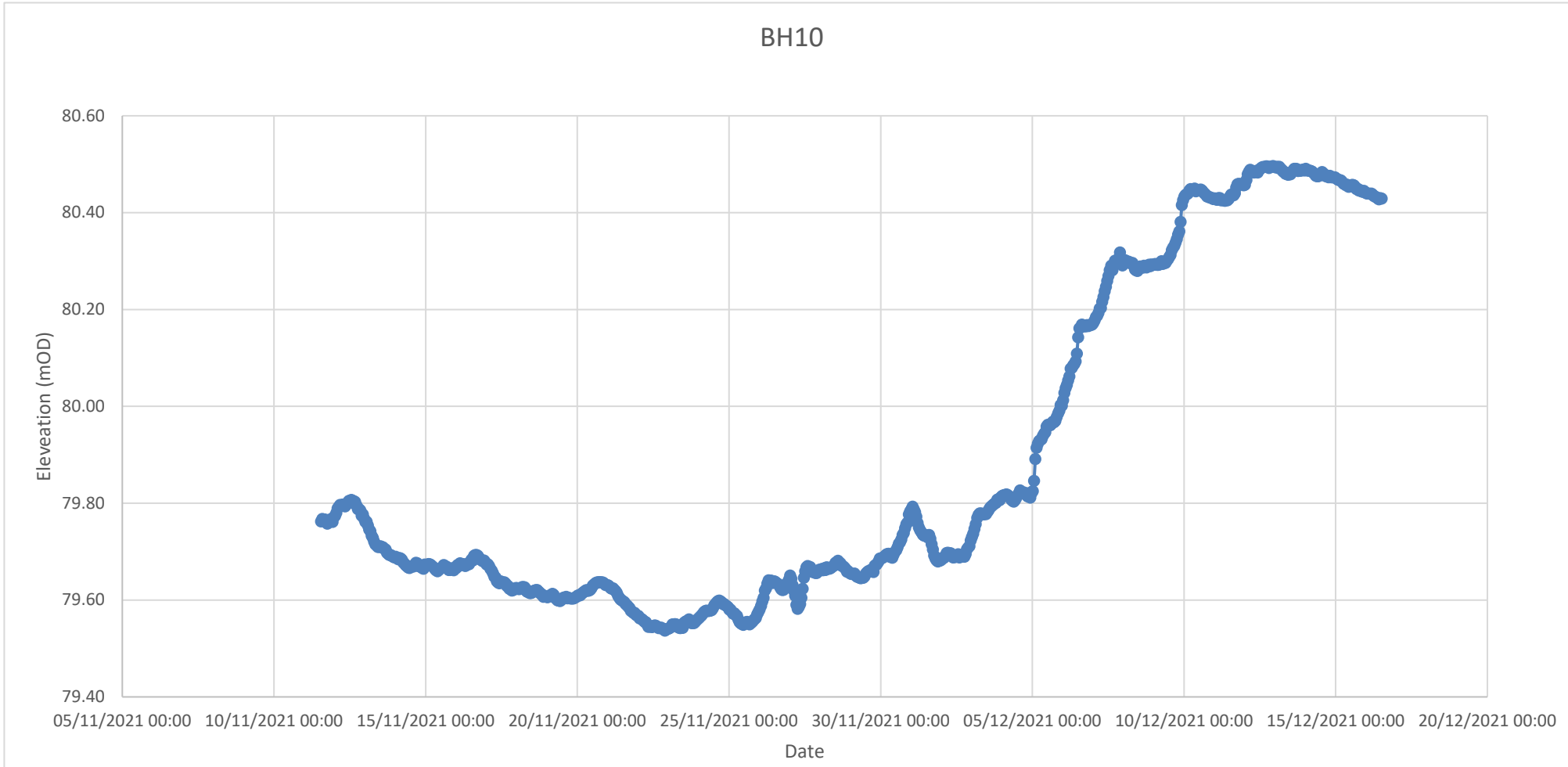
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



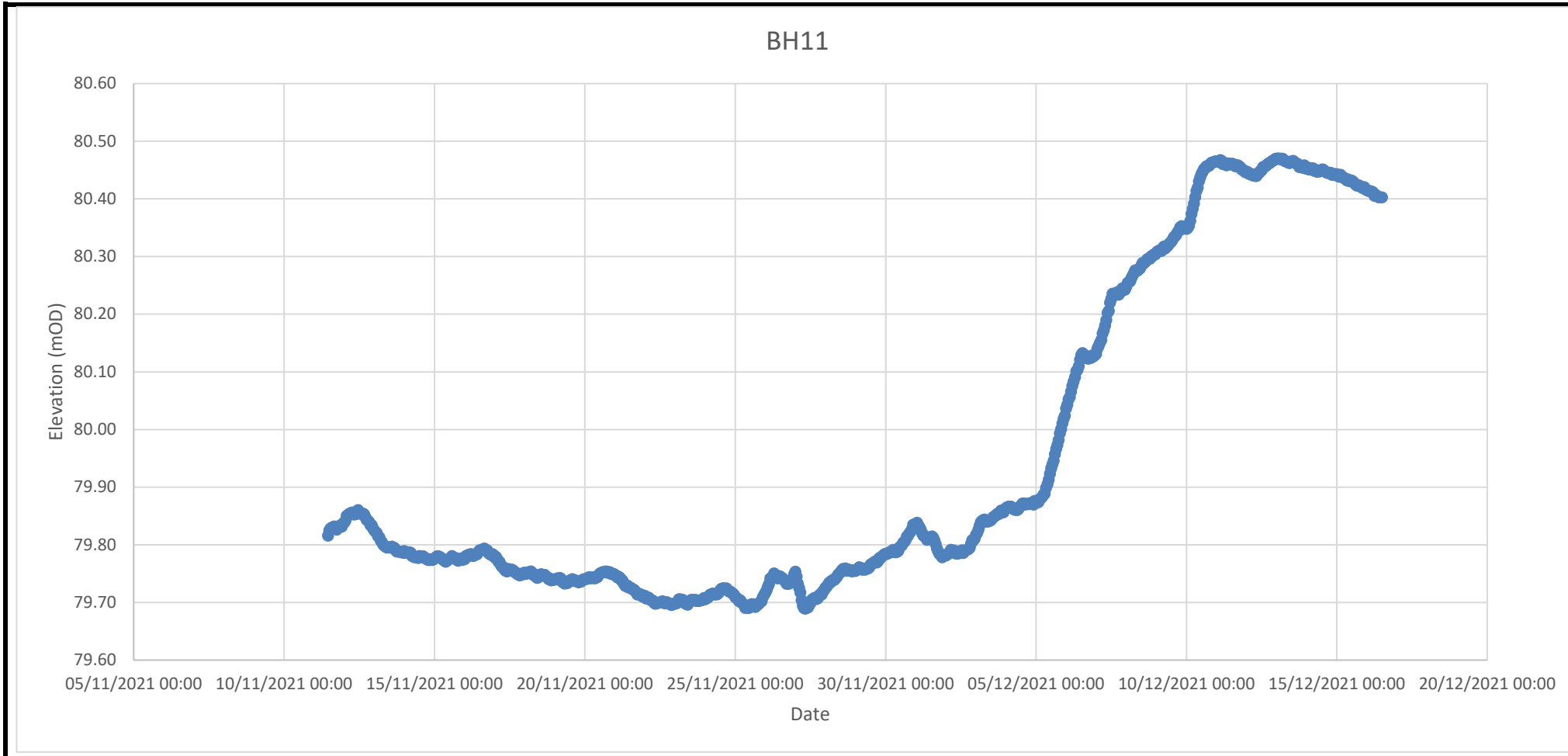
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



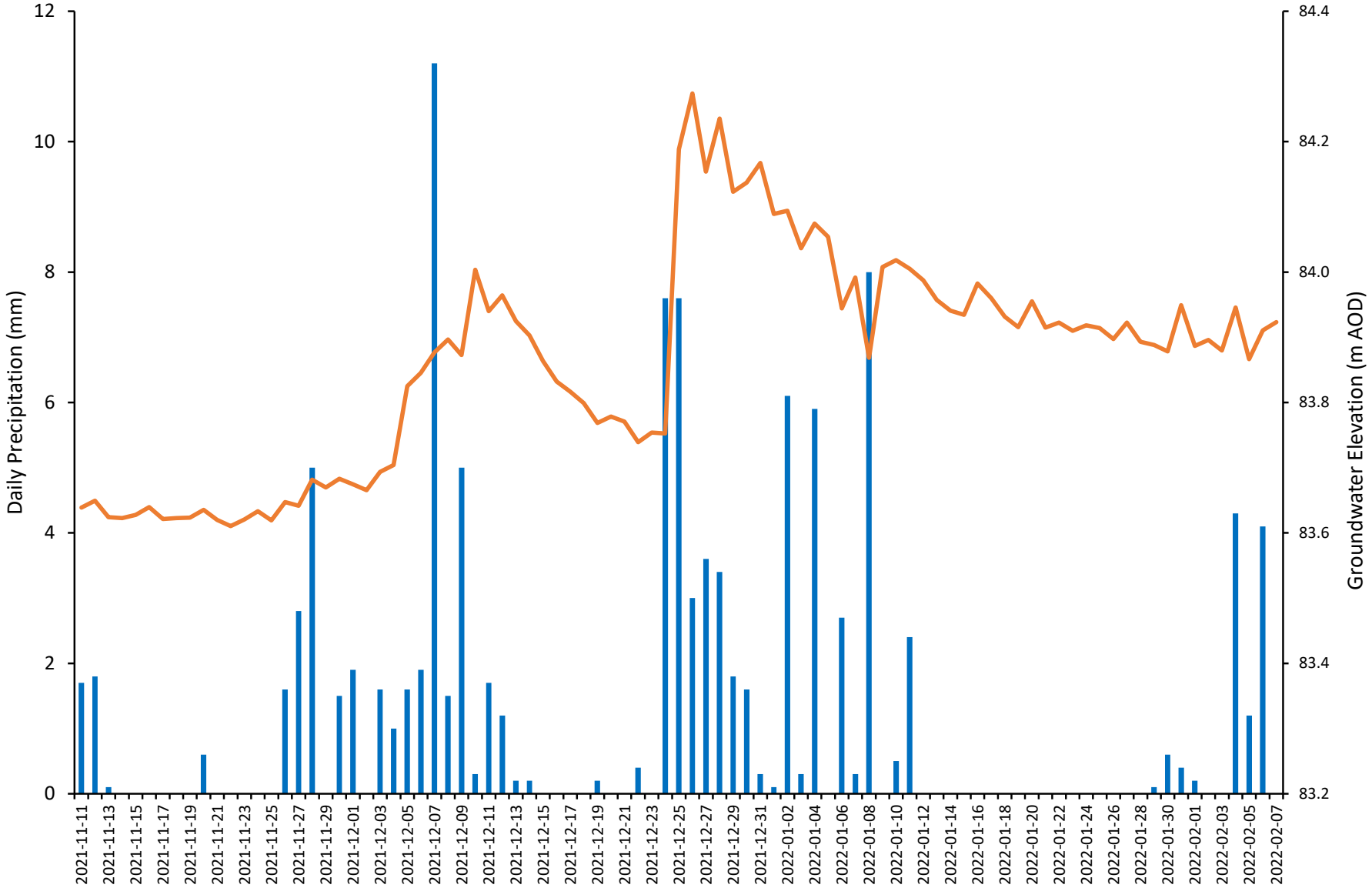
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



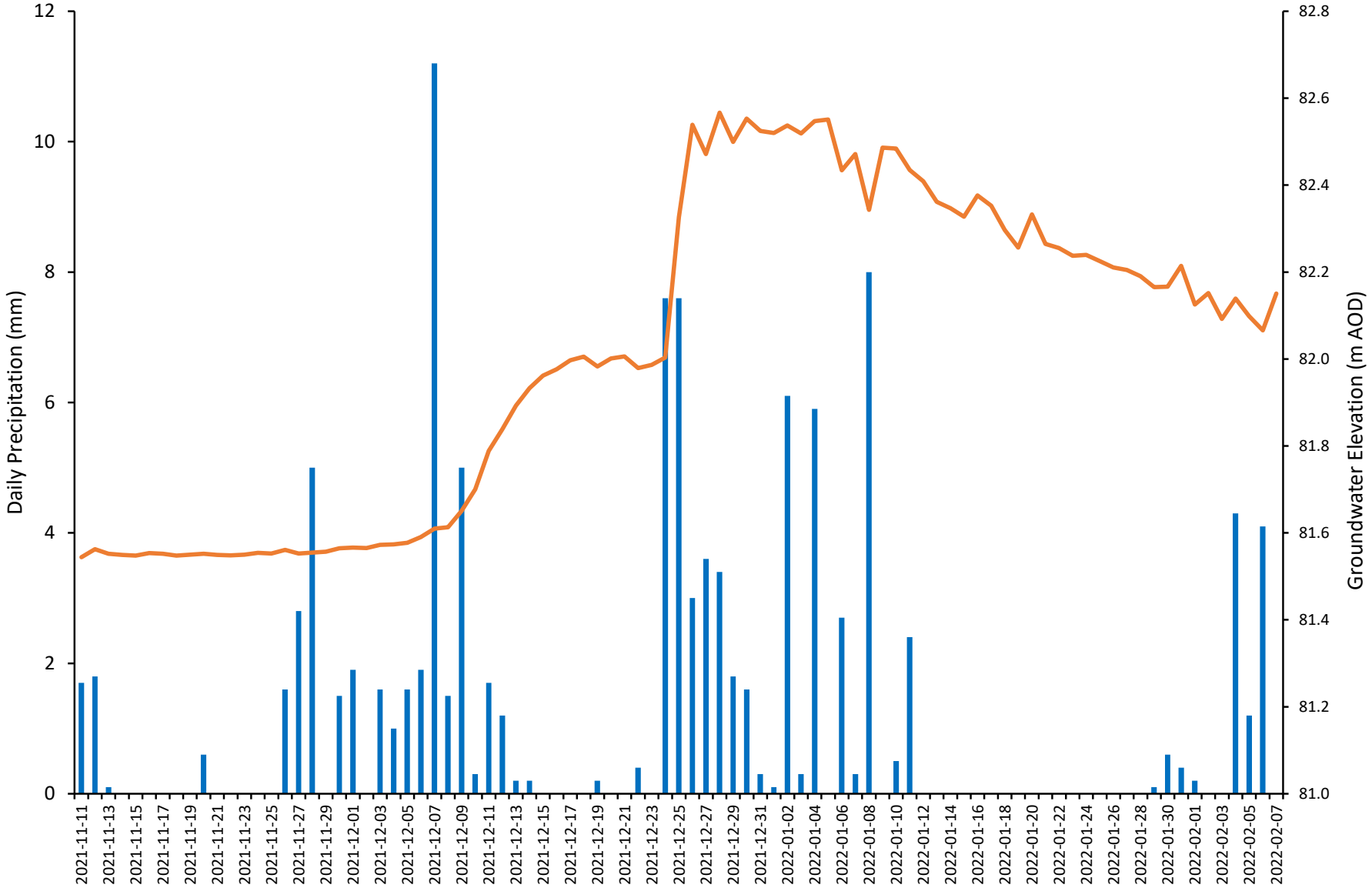
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



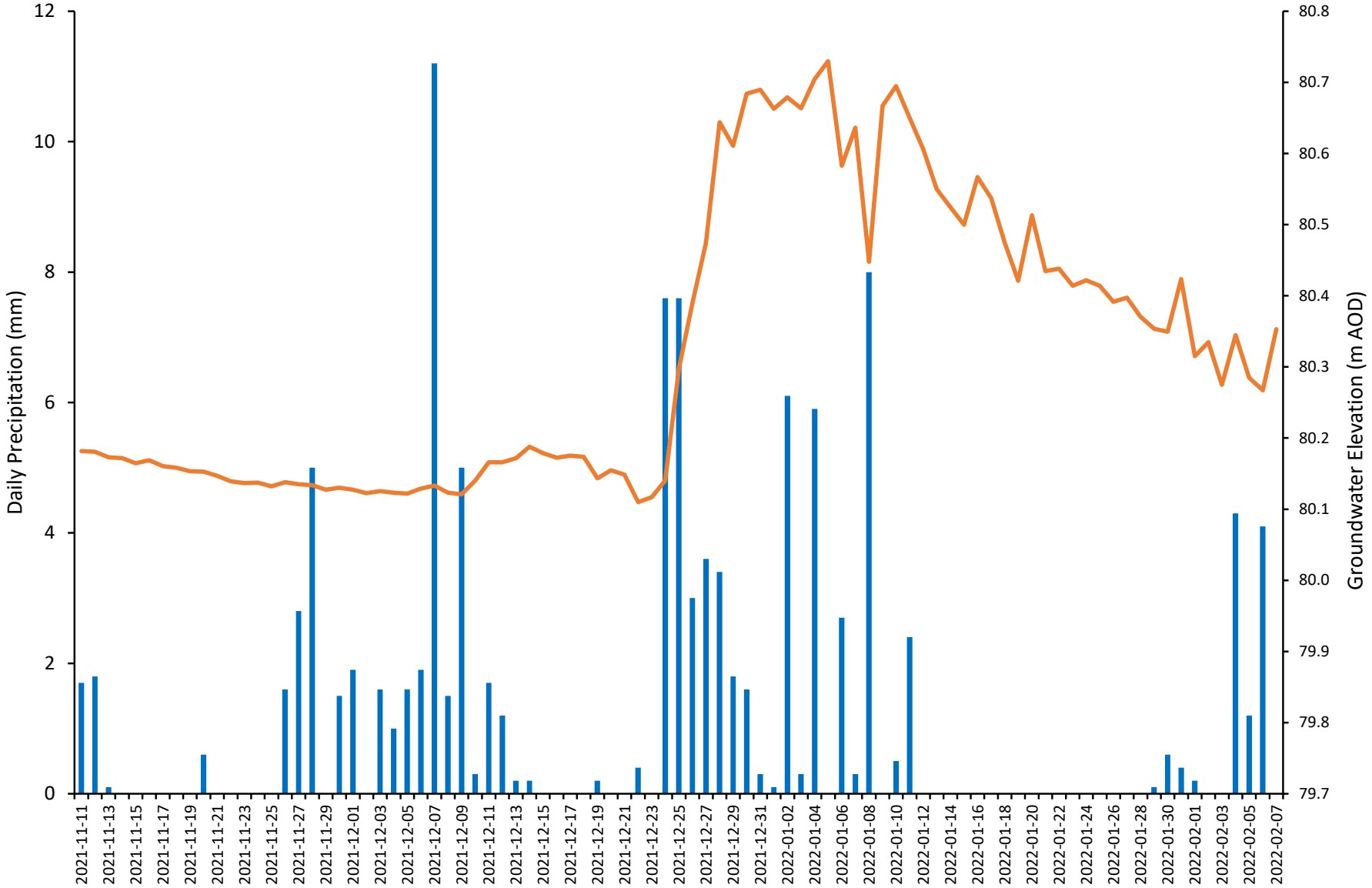
Client	Project	Job No
Great Wolf Resorts Limited	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Monitoring Graphs**	**Figure 12**



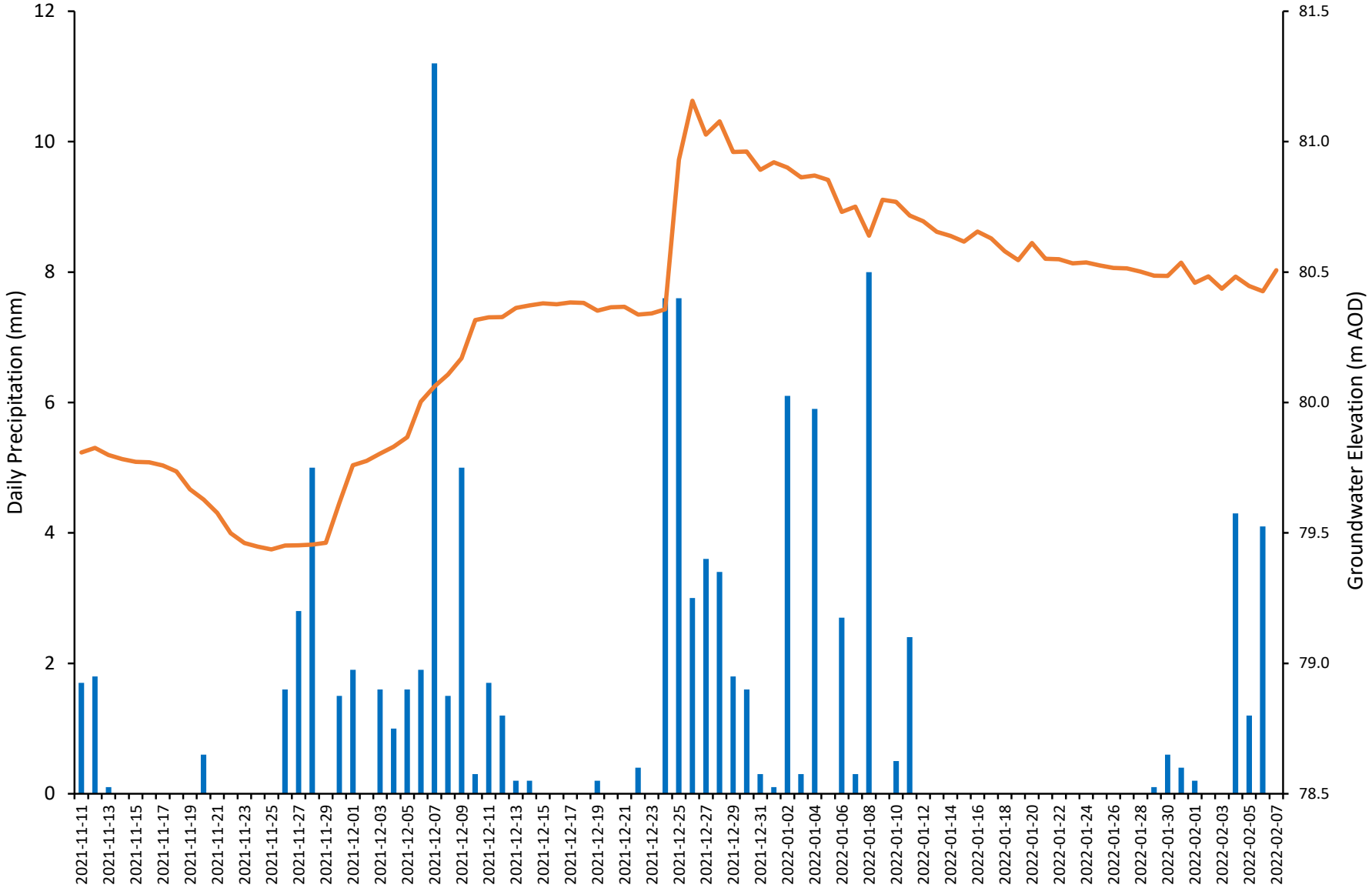
Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Groundwater Levels and Daily Precipitation – BH01**	**Figure 13a**



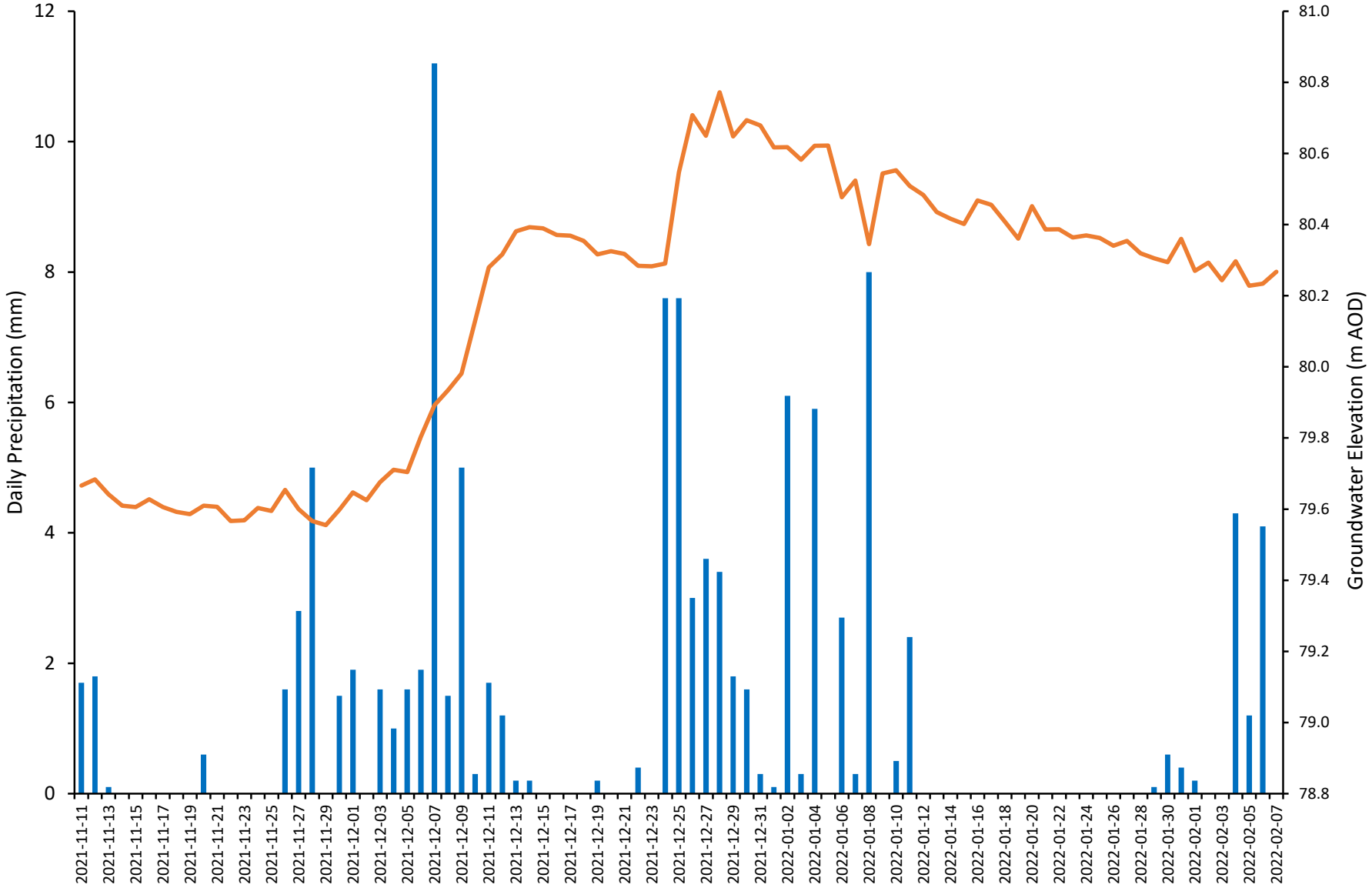
Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Groundwater Levels and Daily Precipitation – BH04**	**Figure 13b**



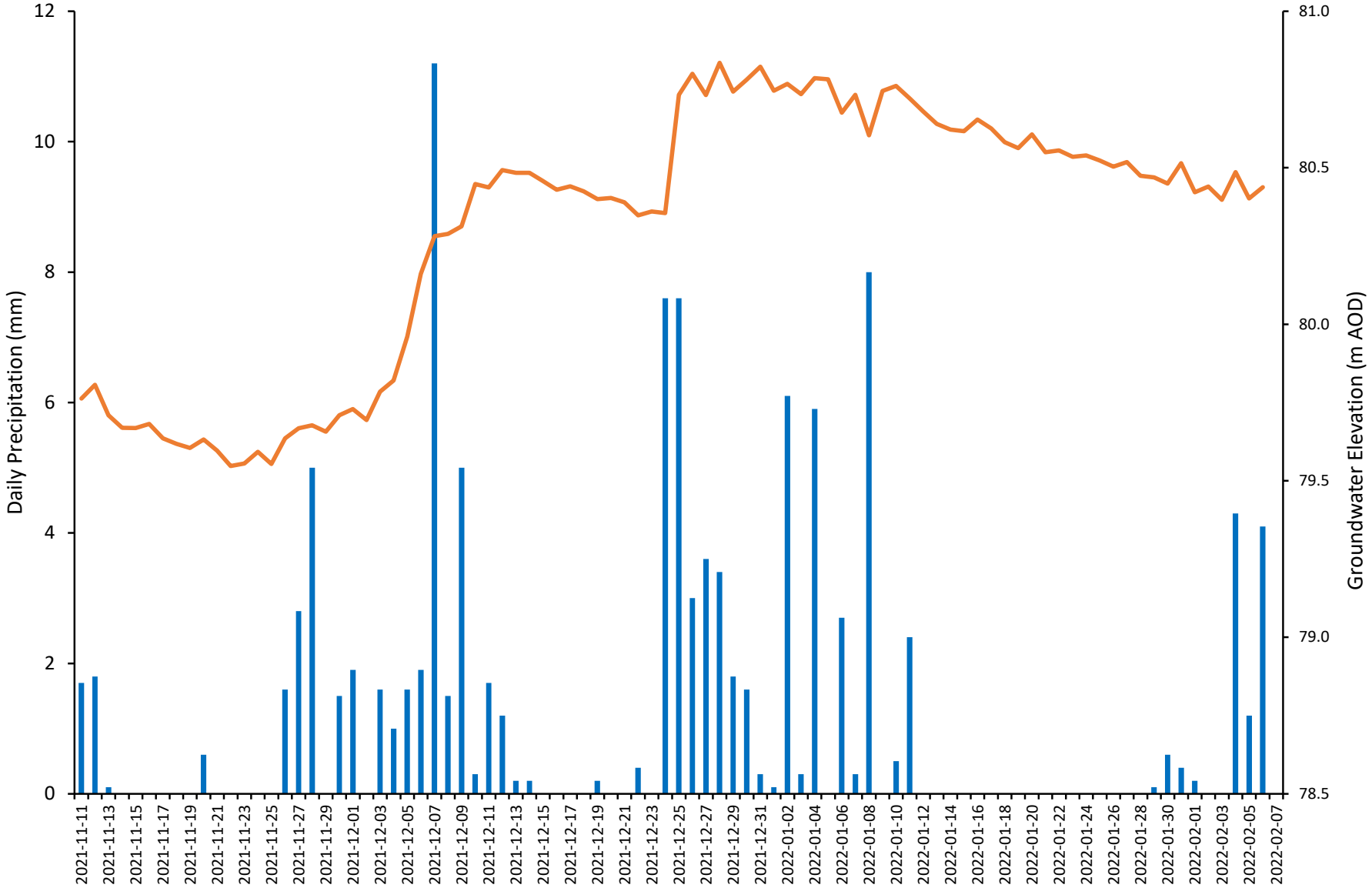
Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Groundwater Levels and Daily Precipitation – BH05**	**Figure 13c**



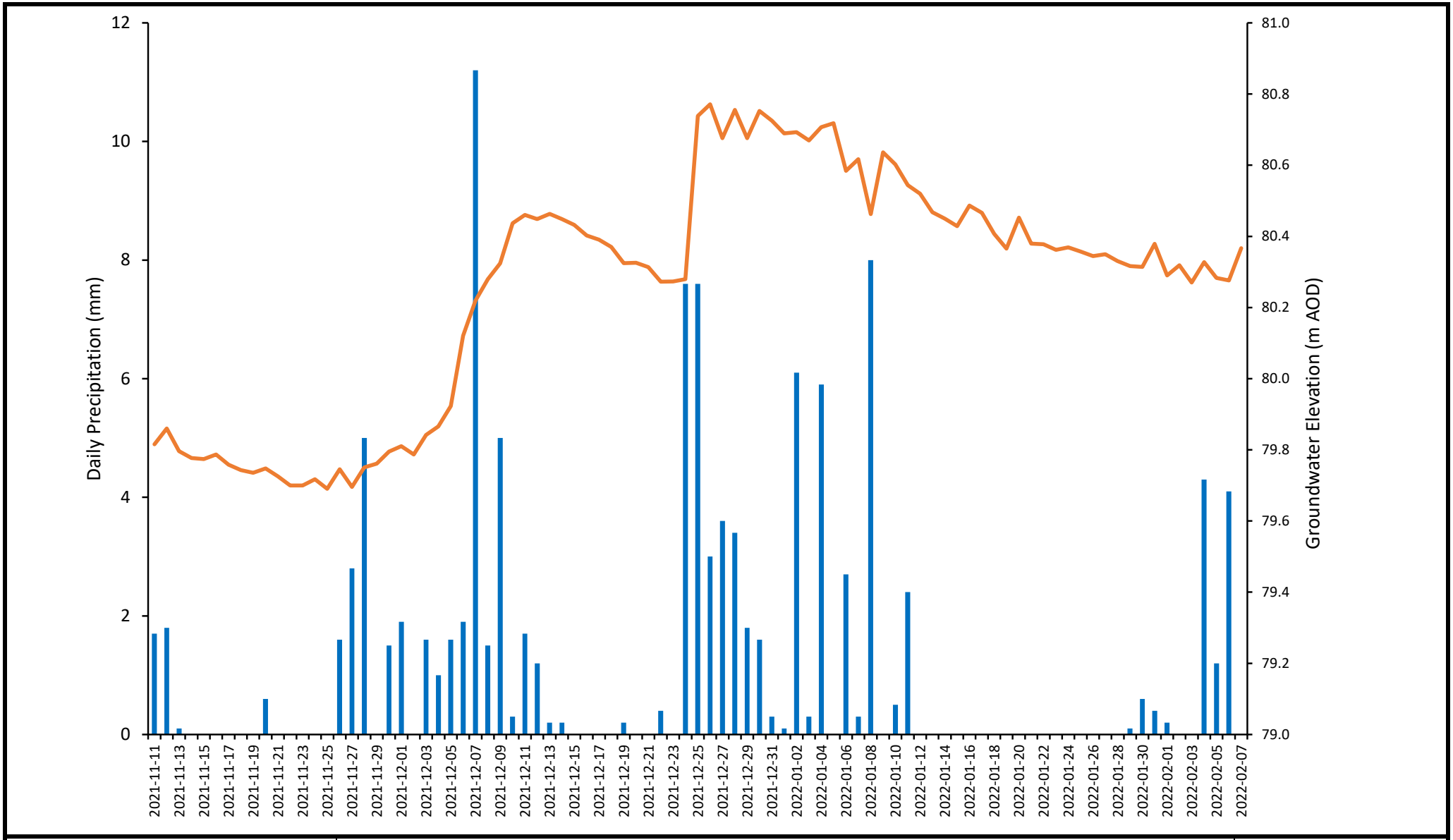
Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Groundwater Levels and Daily Precipitation – BH07**	**Figure 13d**



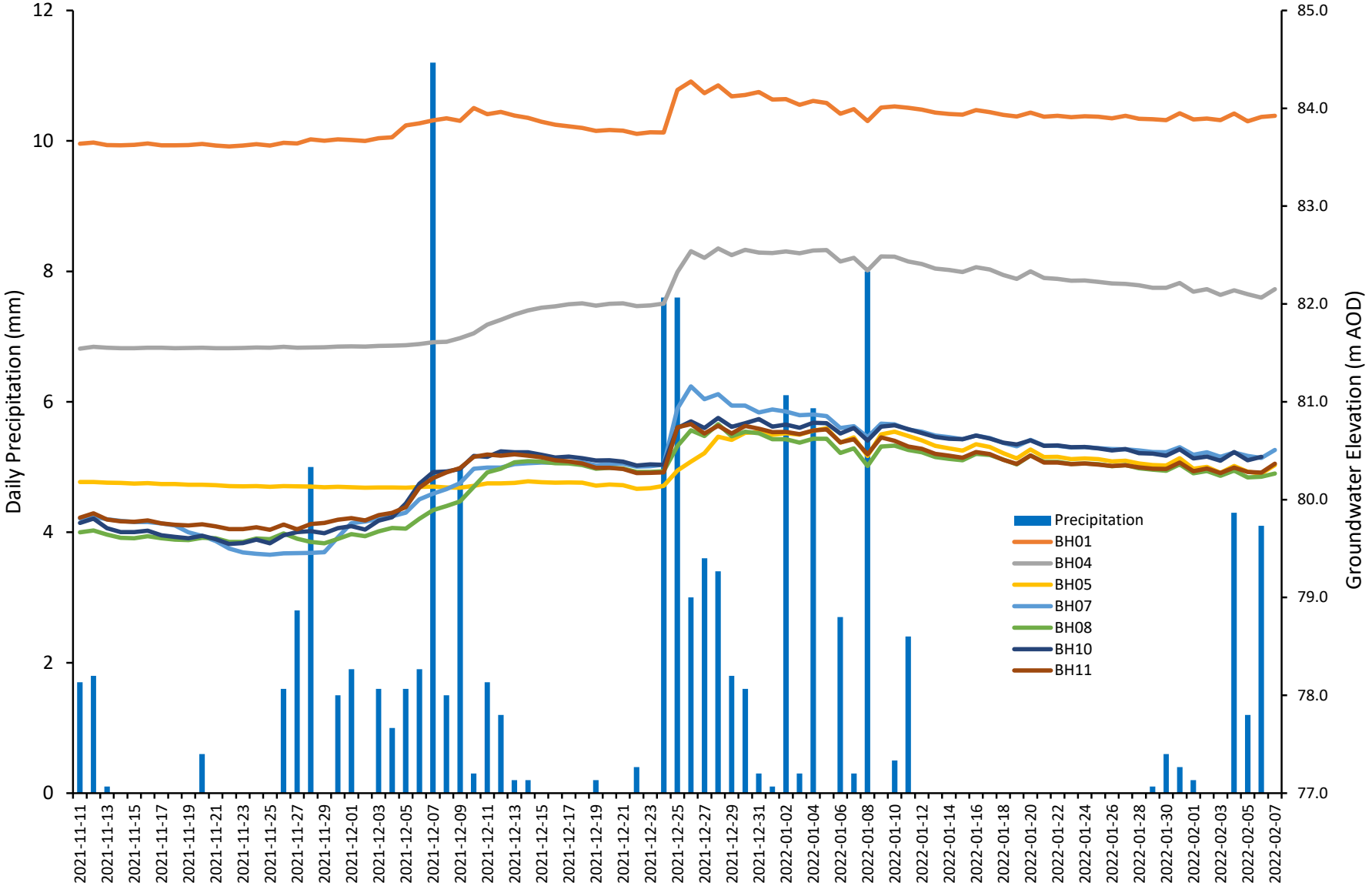
Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Groundwater Levels and Daily Precipitation – BH08**	**Figure 13e**



Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title: **Groundwater Levels and Daily Precipitation – BH10**	**Figure 13f**



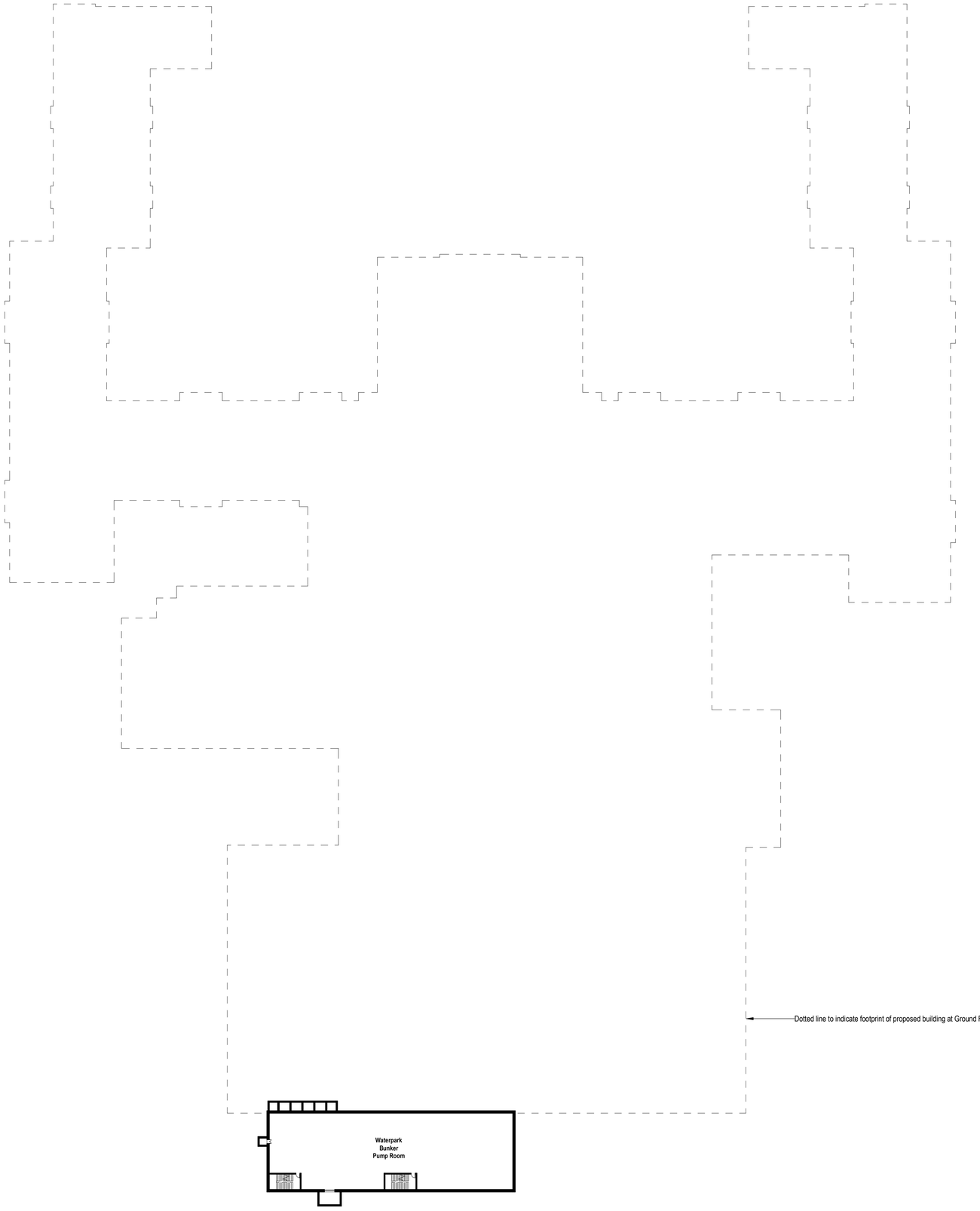
Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Levels and Daily Precipitation – BH11**	**Figure 13g**



Client	Project	Job No
Great Wolf Resorts Ltd.	**Bicester Golf Club, Bicester**	**CG/39017**
CGL	Title **Groundwater Levels and Daily Precipitation - Summary**	**Figure 14**

APPENDIX A

Proposed Development Plan



Dotted line to indicate footprint of proposed building at Ground Floor level

Keyplan

North

Notes:
1. Do not scale
2. Contractor to Check all dimensions and report omissions and errors to the Architect.
3. EPR Architects accepts no liability for use of this drawing by parties other than the party for whom it was prepared or for purposes other than those for which it was prepared.
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No.	Revision	Date	Initial	Chk'd
3	P03 - Planning Issue	08.11.19	LGO	AJ
2	P02 - Preliminary Planning Issue	30.10.19	LGO	AJ
1	P01 - Preliminary Planning Issue	25.10.19	LGO	CT

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5. This drawing is based on project information current at the time of issue. EPR Architects Limited accepts no liability for any alterations to or discrepancies arising out of any change to such project information that occurs to the information after it is issued by EPR Architects Limited.
6. This drawing does not contain shared coordinates and is not issued for coordination purposes.
7. Furniture layouts are indicative and for illustrative purposes only.
8. Structural elements are indicative and for illustrative purposes only.

-5 0 5 10 15 20 25
SCALE 1:500 m

EPR Architects
30 Millbank, London SW1P 4DU
+44(0)20 79327600
www.epr.co.uk

Proposed Great Wolf Lodge
Chesterton, Bicester, Oxfordshire

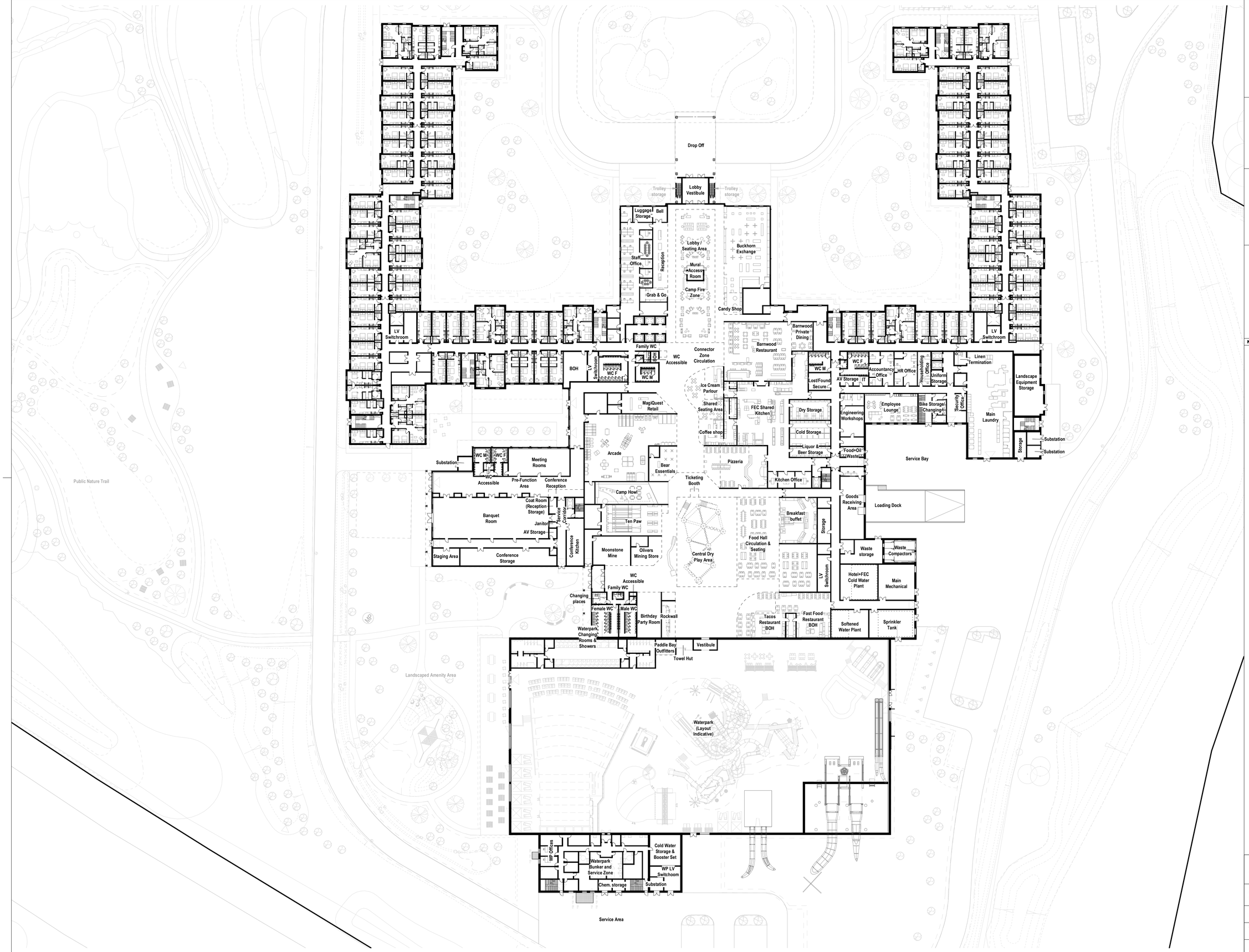
Proposed Basement Plan

Scale @A1	Status	Revision
1:500	Planning	3

Project Code	Originator	Zone	Level	Type	Role	Class.	Number
10875 - EPR - 00 - B1 - DR - A - TP-0199							

C:\Revit\20191007\10875-EPR-ZZ-ZZ-M3-A-CENTRAL_LarkenGoulbert@epr.co.uk.rvt

2019-11-08 11:40:25



Keyplan

North

Notes:
1. Do not scale
2. Contractor to Check all dimensions and report omissions and errors to the Architect
3. EPR Architects accepts no liability for use of this drawing by parties other than the party for whom it was prepared or for purposes other than those for which it was prepared.
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3	P03 - Planning Issue	08.11.19	LGO	AZ
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8. Structural elements are indicative and for illustrative purposes only.

-5 0 5 10 15 20 25
SCALE 1:500 m

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Proposed Great Wolf Lodge
Chesterton, Bicester, Oxfordshire

Proposed Ground Floor Plan

Scale @A1	Status	Revision
1:500	Planning	3

Project Code	Originator	Zone	Level	Type	Role	Class.	Number
10875 - EPR - 00 - GF - DR- A - TP-0200							

2019-11-08 11:40:45