The Cambridge South East Transport Order

Transport And Works Act 1992

Transport And Works (Applications And Objections Procedure) (England And Wales) Rules 2006

Appendix 9.2 – Tetra Tech Report

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
Tt	Tetra Tech
MML	Mott MacDonald Limited
GCP	Greater Cambridge Partnerships
m	Meters
m bgl	Meters below ground level
m AOD	Meters above Ordnance Datum
NGR	National Grid Reference
N, S, E, W	North, South, East, West
PTR	Preferred Transport Route
TH	Travel Hub
HRS	Haverhill Road Stop
HWS	Hinton Way Stop
SRS	Sawhill Road Stop
BH	Borehole
TP	Trial Pit
WS	Window Sample
DS	Dynamic Sample
DCP	TRRL Dynamic Probe Penetrometer
CPT	Cone Penetration Testing
SPT	Standard Penetration Testing
ECW	Environmental Clerk of Works
OLE	Overhead Electric
Ch	Chainage
NI	Non-intact
ND	Not-discernible
NR	No recovery
PLT	Disturbed sample comprising a lump of chalk (deemed suitable for point load test)
CSS	Core sub-sample

1.0 INTRODUCTION

1.1 INSTRUCTION

TetraTech (Tt) were commissioned by Greater Cambridge Partnerships (GCP) to undertake ground investigations along the proposed dedicated public transfer route known as the Cambridge South East Transport (CSET) scheme.

The investigation scope was developed by Mott MacDonald Ltd (MML) and detailed in the ground investigation specification reference: 403394-MMD-HWA-00-RP-HW-0462, dated October 2020 [ref 1].

Schedule 2 of specification, which summarised the position and requirements at each exploratory hole / test location, and the associated exploratory hole locations plans, were later revised, and issued as document ref. Updated_Schedule_2_12032021 Rev 1.

Further adjustments to the scope included the addition of hand auger positions to inform a Soil Survey, and investigations for materials management (known as Borrow Pit (location references headed 'BP')).

A full record of contract change control is provided in Section 3.1.

The investigation was commissioned under the GCP Purchase Order reference 31300064781 dated 26th January 2021.

1.2 BACKGROUND

The preferred route of the dedicated public transport scheme (PTR), together with an alternative alignment at the schemes eastern end, will run between a proposed Travel Hub Option B located approximately 11km southeast of Cambridge City Centre, to the immediate south of the Cambridge Biomedical Campus, on the southern outskirts of Cambridge.

Three stops planned along the PTR and moving north from the Travel Hub (TH), they are identified as Sawston Road (SRS), Haverhill Road (HRS) and Hinton Way (HWS).

They PTR traverses predominantly agricultural land and crosses the River Granta and various drainage ditches at field boundaries.

The investigations were scoped to obtain information on the ground conditions along the PRT, the TH, and the three stops (SRS, HRS and HWS), and were inclusive of investigations over an alternative alignment at the schemes eastern end, referenced as the OBC route. The alternative alignment is based upon the previously considered OBC Alignment which, to the south of SRS, deviates from the PRT taking a different route to the TH.

[1] Ground Investigation Specification ref. 403394-MMD-HWA-00-RP-HW-0462, Mott Macdonald, October 2020

1.3 TERMS AND CONDITIONS

This report has been prepared for the client, GCP, in accordance with the terms and conditions of the contract. The report is prepared in line with the Invitation to Tender and the Tt tender submission (December 2020) and is subject to the report conditions included as Appendix B.

The recommendations and opinions expressed within this report are based on the information provided and other sources of readily available information. Where reference has been made to other reports or information provided by the client, or from other Third-party sources, such data has been reviewed in good faith and it has been assumed that their contents are correct, as it is impractical to fully validate this data. Tt is unable to guarantee any Third-Party Information.

The ground conditions presented herein are representative of the conditions recorded at the time and in the positions of the investigation. Ground conditions may vary over time (particularly hydrogeological status and migration/breakdown of contamination) and in between investigation locations.

2.0 SITE INFORMATION

2.1 SITE LOCATION AND DESCRIPTION

The investigations discussed herein extend from approximate National Grid Reference (NGR) 546013, 254447 in the NW, to 551846, 249533 in the SE (see Figure reference: B025563-TTE-00-XX-DR-U-0001-P02 Site Location Plan (Appendix A)). The ground investigations cover the linear route of the PRT and OBC which extends over approximately 8.50km, with focused investigations at the proposed stops along the route at TH, SRS, HRS and HWS.

At the time of the intrusive investigations (between 8.2.21 and 5.5.21), the majority of the PRT and OBC and stops, and the associated exploratory locations, were undertaken within arable farmland. The only exception is the northeast extremity which extends across a cycle track and onto the southern verge of the Addensbrooke Road.

Investigations were therefore undertaken under access licenses arranged between GCP and private landowners of various fields along the route (sub areas) as indicated in Figure references B025563-TTE-00-XX-DR-U-0002-P02 Site Investigation Layout Plans (Sheets 1 to 13 inclusive, Appendix A).

Key features and summary details of each sub area at the time of the intrusive investigations are summarised in Table 1.

Table 1 Subsite Summary Details

LR Tile Ref.	Exploratory Holes	Summary Description
CB345398 Ch 600 to 700 'Pemberton's Track'	BH-PTR-01 and BH-PTR-02	Investigations in this area were undertaken on the flat at the base of the Addenbrooke Road embankment. Work was completed under a Section171 road licence (ref. S171/2021/016) which covered an area to the N and W of a cut drainage channel, and N of an access road and cycle track.
CB366757 Ch 700 to 900 'Pemberton's'	BH-PTR-03 to BH-PTR-07	This area comprises a flat arable field with a slightly raised access track connecting with Pemberton's Track which runs along the W boundary. A Network Rail track lies further to the E. A stream flows from E to W along the S boundary. A pedestrian / cycle track bridge crosses the stream and connects to the track continuing to the south. Cadent infrastructure (buried services) is shown on services plans to run along the north boundary. An MML ECW confirmed the presence of water vole burrows near to the stream bank.
CB366757 Ch 900 to 2750 'Garnham's Fields'	BH-PTR-08 to BH-PTR-14 TP-PTR-02 to TP-PTR-16	This area comprises an arable field and mature wooded plot sloping to the west at approximately 3°. The tile is centrally bisected by Granham's Road which provides vehicle access to the fields to the NW and SW respectively. Ponded archaeological excavations awaiting dewatering remained open during the ground investigations undertaken in the north of this area. The SE area is subdivided by a mature hedgerow. Possible badger sets were noted in the hedgerow during the investigation and were reported to MML / ECW prior to undertaking intrusive work. The area defined to be of High Risk of UXO encounter extends into the southeast (see Section 2.6).

LR Tile Ref.	Exploratory Holes	Summary Description
CB432941 Ch 2750 to 3800 'Hinton Way'	HWS locations BH-PTR-15 to BH-PTR-17 TP-PTR-17 to TP-PTR-23	This area comprises an arable field accessed from Hinton Way which extends to Haverhill Road and slopes to the southwest by approximately 3°. The High Risk UXO Zone extends across the entire field (see Section 2.6).
CB365174 Ch 3800 to 4000 'Deal - HRS'	HRS locations BH-PTR-18 TP-PTR-24 to TP-PTR-25	This area, which is within the High Risk UXO zone (see Section 2.6), comprises the corner of field located SW of Haverhill Hill Road and slopes gently to the SW by approximately 1° .
CB383158 Ch 4000 to 4925 'Bury Farm'	BH-PTR-19 to BH-PTR-28 TP-PTR-26 to TP-PTR-30 CPT-PTR-01 to CPT-PTR-03	This area was accessed from a public right of way (track) leading E from Haverhill Road through Stapleford Granary which subdivides the fields into two portions. The land N of the track comprised deeply furrowed arable land with undulations of up to 1m lying partially within the SE extent High Risk of UXO Zone (see Section 2.6). The S area is divided by a drainage ditch and hedgerow with arable fields on each side. The area to the south slopes towards the River Granta by approximately 1° and the banks of river form the vegetated south boundary. Badger sets were noted near to the riverbank and this area was notably boggy during the early stages of the investigation.
CB365174 Ch 4925 to 5425 'Deal'	BH-PTR-29 to BH-PTR-40 TP-PTR-25 to TP-PTR-31 TP-BP-01 to TP-BP-05 BH-BP-01	The PTR crosses the NE corner of this field and is accessed from a track leading NE from Cambridge Road and extending to the PTR through a broken hedgerow bounding the S edge of a slightly sloping (by approximately 2°) boggy arable field. The field slopes towards the River Granta which forms the NW boundary. A medium pressure gas main, managed by Cadent, runs adjacent to the access track, and crosses both the PTR and the River Granta. Cadent attended site on 11.3.21 to check the gas main location (which was confirmed to align with the marked boards on the banks of the River Granta) and attended again on 21.2.21 to approve the access bridge constructed as part enabling works risk mitigation, which included exposure of the gas main in hand excavations prior to accessing the exploratory holes north of the gas main. Overhead Electric Cable routes (OLE) crossed the central areas of these fields. The BP area is the within the field to the NE of this area and is separated by a mature broken hedgerow. The full perimeter of this area is under stewardship (SW1 classification) requiring a 4m buffer onto the cultivated land, and AR1 / 8 classification land where access was not permitted. This required some minor adjustment of the scoped positions as detailed in Section 3.1.
CB272622 Ch 5425 to 6050 'North Farm (Lot 1 and 2)'	BH-PTR-41 to BH-PTR-44 TP-PTR-32 to TP-PTR-36	This section follows the SE boundary of a field adjoining the landscaped gardens of North Farm, which was accessed through private residential double vehicle gates on Dale Manor business park. The PRT is immediately NE of a historic railway line and Birch saplings had recently been planted along the SW section of the PRT within this area. The extreme NW of this area was densely vegetated with brambles resulting in minor adjustments to the scoped locations (Section 3.1).

LR Tile Ref.	Exploratory Holes	Summary Description
CB355304 Ch 6050 to 6450 'Deal - Manor Dale'	TP-PTR-38 to TP-PTR-40	This area comprises open arable field accessed from North Farm.
CB351799 Ch 6450 to 6900 'Sawston Rd'	SRS Stop BH-PTR-45 TP-PTR-43 to TP-PTR-44 TP-OBC-01 to TP-OBC-07	This area comprises arable open fields accessed from Sawston Road. OLE crosses the SE corner.
CB351799 Ch 6900 to 8500 'OBC South'	BH-OBC-01 to BH-OBC-07 P-OBC-09 to TP-OBC-13 CPT-OBC-01 & CPT-OBC-02	The OBC route crosses over High Street and continues across arable fields which were deeply furrowed (up to 1m) at the time of the investigation. The field slopes gently by approximately 2° towards the River Granta which forms the north boundary of this area. Exploratory holes where accessed from OBC North / Cheveley (see below) via a concreted fjord crossing the River Granta in the NE of this area. Field irrigation water pipes crossed the River from a pump station situated immediately to the east of the fjord.
CB351799 Ch 8500 to 8750 'OBC North'	BH-OBC-08 to BH-OBC-16 CPT-OBC03 & CPT-OBC04	The north side of the OBC river crossing was accessible from a track leading from Cheveley Park Farm located on High Street (also known as Home Farm). The track included a section of public right of way leading E from the farm, and a farm track heading S to the River. The south boundary of the field, immediately to the north of the river, is under land Stewardship (designated EF1). A high-pressure gas main (HP) crosses the field from N to S approximately 140m E of BH-OBC-16.
CB351799 Ch 8950 to Termination 'Travel Hub'	TH Positions	The area of the proposed travel hub was accessed via a public right of way leading east from Cheveley Park Farm. The track crosses the HP gas main and an officer from National Grid (NG) attended site on 25.2.21 to confirm the requirements for a load spreading bridge along the track constructed prior to accessing TH positions. TH Covers a rectangular area of arable fields covering approximately 11Ha spreading N and S of the public track. The A11 and A1307 form the E and N boundaries respectively. The wooded area in the NE houses badgers sets and a vagrant. The wooded area to the S is under stewardship (EF1 designation) and includes a pond.

2.2 ANTICIPATED GEOLOGY

The ground investigation specification and desk-based assessment [ref 2] include a summary of the anticipated ground conditions abstracted as follows.

Artificial Ground

The British Geological Survey (BGS) 1:50,000 Series Solid and Drift Geology Map (England and Wales Sheet 205 – Saffron Walden); the Landmark Envirocheck Report; and the BGS Geology of Britain Online Viewer do not indicate artificial ground within the scheme footprint or close proximity. At this scale, artificial ground deposits of less than 2.5m thickness are not shown. Hence, further deposits may still be found along the scheme, particularly in areas proximal to development.

Superficial Deposits

The BGS 1:50,000 Series Solid and Drift Geology Map (England and Wales Sheet 205 – Saffron Walden); the Landmark Envirocheck Report; and the BGS Geology of Britain Online Viewer indicate that Alluvium Deposits and River Terrace Deposits are likely to be encountered on site, primarily constrained to the land adjacent to the River Granta.

Bedrock Deposits

The BGS 1:50,000 Series Solid and Drift Geology Map (England and Wales Sheet 205 – Saffron Walden); the Landmark Envirocheck Report; and the BGS Geology of Britain Online Viewer show that the scheme is primarily underlain by a succession of marine, south-easterly dipping Cretaceous Chalk units. This series of Chalk units can be split into two subgroups: the older, Grey Chalk Subgroup (c. 100.5 to 93.9 Ma) and the younger White Chalk Subgroup (c. 93.9 to 66 Ma), which together compose the Chalk Group.

The Grey Chalk Subgroup has a high percentage of clay and therefore marls are found within the component units, whereas, the White Chalk Subgroup contains on average greater than 98% CaCO3. The higher content of clay within the Grey Chalk Subgroup indicates that deposition of this unit occurred closer to land, where land derived sediments could mix with the calcareous coccoliths during deposition. In contrast, the White Chalk Subgroup indicates deposition further from land, resulting from the Late Cretaceous marine transgression (Mortimore, Wood, & Gallois, 2001).

Structural Geology

Worssam & Taylor (1969) states that two main episodes of folding are recorded within the rocks of the Cambridge district. The first episode occurred post-deposition of the Kimmeridge Clay Formation, but pre-deposition of the Lower Greensand Formation. The second episode of folding, affected all units, including the Late Cretaceous rocks of the Chalk Group. The most prominent fold is called the Upware Anticline, which strikes NWE-SSW. A corresponding syncline can be found striking parallel to the Upware Anticline, with its axis c. 1.6km to the west.

[2] Mott MacDonald Limited. 2019. A1307 Cambridge South East Transport - Phase 2 – Geotechnical and Geo-environmental Preliminary Risk Assessment (Ref: 403394-MMD-TGE-00-RP-GE-0001)

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In general, a south-eastern dip is noted across the region, but this can be locally disrupted by minor folding.

Table 2 is also abstracted from the specification and provides a summary description of the anticipated sub-units together with the anticipated thickness and the chainage / location in age succession (from young to old).

Table 2 Summary of Units (abstracted from the specification)

Unit	Parent Unit	Typical Description	Typical Thickness	Chainage (s) / Location
Alluvium	Superficial Deposits	Soft to firm, compressible silty clay, which may contain layers of silt, sand, gravel and peat. Primarily composed of material reworked from earlier superficial deposits and Chalk bedrock. Occasionally logs are found within peat.	<3m	Site wide
River Terrace Deposits	Superficial Deposits	Sand and gravel, locally with lenses of silt, clay or peat.	<10m	Site wide
Lowestoft Formation	Superficial Deposits (Glacial Till)	Dark blue-grey, stiff, unstratified silty clay with an abundance of chalk and flint fragments and less commonly other rocks including Triassic quartzite and other miscellaneous igneous and metamorphic rocks. The unit is deposited in extensive sheets	<55m	Off site to the north of TH with potential encorachment
New Pit Chalk Formation	White Chalk Subgroup	Blocky, white soft to moderately hard chalk with numerous marl horizons. Flint occurs sporadically in the upper part of the unit and within the lower unit towards the margins of the outcrop and at structural highs.	70m	Off site
Holywell Nodular Chalk Formation	White Chalk Subgroup	Hard nodular chalk with thin flasar marls and a large proportion of shell debris in parts. The base of the unit is marked by the Melbourn Rock Member and chalk of the Plenus Marls Member	12 to 30m	Ch 0 to 2700 Underlying TH
Melbourn Rock Member	Holywell Nodular Chalk Formation	Hard to very hard off-white, blocky fractured chalk with numerous nodular chalk beds and thin marls. Nodules are cream in colour and are composed of gritty chalk.	2 to 3m	Non-discernible
Zig Zag Chalk Formation	Grey Chalk Subgroup	Mostly firm, blocky chalk which is pale grey at its base to cream/off-white higher in the unit. The lower portion of the unit is characterised by rhythmic alternations of marls and marly chalks with firm white chalk. Thin gritty, silty chalk beds act as markers in the sequence. The unit often displays nearly horizontal, curvilinear jointing.	24 to 32m	Ch 2700 to 6400

Unit	Parent Unit	Typical Description	Typical Thickness	Chainage (s) / Location
Totternhoe Stone Member	Zig Zag Chalk Formation	Hard, brownish grey, fossiliferous, fine grained, thin to thickly bedded calcarenite. The unit is well jointed and contains phosphatic nodules, particularly at it base. These green coated pinkish brown nodules vary in size between a few millimetres across to several centimetres. The higher beds of the unit are described as a fine calcareous sand consisting chiefly of fine, well graded shell fragments	>0.9m	Non-discernible
West Melbury Marly Chalk Formation	Grey Chalk Subgroup	Buff, grey and off-white, interbedded soft marl and hard grey limestone. The Cambridge Greensand Member is encountered at the base of the unit and is described as a fossiliferous, phosphatic marl with much glauconite sand. The lower beds of the unit are blue-grey marls which closely represent the mudstones of the Gault Formation below. The unit has an unconformable base, marked with an erosion surface; whereas its uppermost surface is conformable and marked by the erosional surface of either the overlying Zig Zag Chalk Formation or Totternhoe Stone Member. Occasional pyritic nodules are noted in the upper portion of the unit.	25 to 30m	Ch 6400 to 7600

Nb. References removed (refer to the specification [ref 2])

The specification also provides a more detailed review of historic BGS borehole logs to assess the anticipated geology in local areas of the site. This information has been considered when applying nomenclature to the units encountered.

2.3 HYDROGEOLOGY

The specification indicates that the Alluvium and River Terrace Deposits are classified as Secondary A Aquifers with high groundwater vulnerability. The Lowestoft Formation (Glacial Till) is classified as a Secondary Undifferentiated aquifer with high groundwater vulnerability.

Both Chalk Groups (White and Grey) are classified as Principal Aquifers with medium to high groundwater vulnerability, and Groundwater Source Protection Zones cover the SE are of the site.

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2.4 CONTAMINATION

The following extract from the specification summarises potential contamination sources.

- Onsite and offsite historical landfill sites;
- Artificial Ground and associated contamination from past and current structures / infrastructure / historical mining / infilled pits;
- Potential asbestos from demolished historical structures and within soil;
- Existing and historical infrastructure which traverse and / or surround the site such as the Cambridge-London Railway and disused railway along with traffic using surrounding roads could be a potential source of hydrocarbons (e.g. via fuel and / or oil leaks) and airborne particulates;
- Large areas of the site and surroundings are currently designated as agricultural fields so agricultural pesticides and sewage sludge may have been applied to the ground, with localised fuel / oil spillages from agricultural machinery possible;
- Ground gases generated from Artificial Ground and organic materials in Alluvium Deposits;
- Numerous surrounding industries such as historical mining, farming, engineering works and depots, along with businesses such as fuel stations, garages, tyre dealers, cleaners and waste disposal services which are present in the surrounding area;
- Chemicals, fuels and hydrocarbons stored in tanks could be a potential source of contamination through spillages; and,
- Sewage farms and pumping stations may result in contamination associated with chemicals associated with water purification.

2.5 SERVICES

Service plans provided by statutory undertakers were included as part of the pre-construction information and amalgamated into a single constraints plan [ref 3] referred to as part of service clearance procedures conducted prior to ground disturbance at each exploratory hole location.

Key service-related constraints, and risks mitigated during the investigations are summarised as follows.

- In consultation with Cadent and National Grid, load spreading bridges were placed along the access routes crossing the MP and HP gas mains on Deal Land (at NGR 548395, 251197) and Cheveley Park (at NGR 541852, 249874) respectively.
- To positively identify and confirm the location and depth of the MP gas main crossing Deal, two machine excavations were excavated across the access route under the supervision of a Cadent engineer.

[3] Drawing ref 403394-MMD-XX-00-GIS-YG-0012 to 403394-MMD-XX-00-GIS-YG-0024 inclusive

- The service plans show various statutory services in the vicinity of the proposed exploratory holes within Pemberton's and Ground penetrating radar (GPR) was employed to aid service location along the Pembertons track and surrounding areas to provide options for alternative locations
- TP-PTR-24 in Deal encountered red plastic mesh and a 300mm wide concrete obstruction at a depth of 0.90m bgl, suggestive of a possible service. Adjustments along the alignment (approximately 218°) were therefore adjusted (see Section 3.1).
- An EM CAT signal within the base of the inspection pit for BH-PTR-44 resulted in the relocation of the borehole to BH-PTR-44A. An obstruction within the inspection pit in BH-PTR-43 also resulted in relocation, and an unchartered service route (possibly redundant and associated with the former rail track) is thought to follow the alignment through North Farm.

2.6 UNEXPLODED ORDANCE RISK (UXO)

A preliminary UXO Risk Assessment undertaken by 6 Alpha [ref 4] was provided as part of the specification. This document reports a very low WWII bomb strike density over the full extent of the site, however it also notes that Pampisford Camp (60m S of the PRT) and Babraham Park Camp (210m N of the PRT) present possible air raid targets, and that there are also records of incendiary bomb strikes in the area between Hill Road and Trumpington Road (520m N of the PRT). All of which present risk areas that could encroach into the site.

The report therefore concluded that a detailed UXO Risk Assessment should be undertaken to confirm the overall High-Risk rating across the site.

At the beginning of the site works programme, on instruction of CE notice 002, Tt commissioned Brimstone to undertake a focused UXO Risk Assessment [ref 5] with the primary aim of establishing risk zoning across the site. This focused assessment, included as Appendix N, concludes that the area between approximate NGR 547250, 253136 and 548106, 251667 (between TP-PTR15 and TP-PTR-28) should be considered to carry a potentially elevated risk of UXO and that an EOD Engineer should be in attendance during ground investigations within this zone.

[4] Preliminary Unexploded Ordnance (UXO) Threat Assessment, 6 Alpha (June 2019), report ref. P7401
[5] Stage 1 Preliminary UXO Risk Assessment, Brimstone Site Investigation (15.2.21), report ref. PRA-21-1392

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3.0 TETRA TECH INVESTIGATION

3.1 SUMMARY OF COMPLETED SCOPE AND VARIATIONS

The intrusive ground investigations were completed in general accordance with the specification between the 8.2.21 and 5.5.21.

Confirmation of the relocation or removal of various positions was detailed in the revised Schedule 2 issued by MML on 5.2. 21.

Table 3 summarises specification adjustments and variations resulting from constraints, site conditions or limitations of methodology that were required during the site investigation programme.

Table 3 Summary of Adjustments and Variations

Location	Adjustment / Variation	Rationale
TP-BP-01 to TP-BP-05 inclusive and BH-BP-01	Additions to scope	Post instruction additions to investigate and obtain large bulk samples of coarse soils within the proposed borrow pit area.
BH-PTR-01	Moved to BH-PTR-02	Relocated due to slope and width constraints on the N side of the drainage ditch
BH-PTR-02	Relocated 20m S and 19.5m W	Moved due to adjusted BH-PTR-01 position.
BH-PTR-03	Redrilled (see BH-PTR-03A)	Borehole redrilled with amendments to UT100 sampling specification due to concerns regarding the core recovery.
BH-PTR-06 and BH-PTR-07	Relocated 4m E.	Boreholes relocated into the field area to avoid obstructing the access track.
BH-PTR-06	Revisited to redrill with a Window Sample (WS) rig.	Revisited to obtain UT100 samples of shallow soils using standard percussive drive methods (see Section 3.2.2). UT100s at BH-PTR-06A could not be obtained due to damaged UT100 equipment resulting in an additional revisit (BH-PTR-06B).
BH-PTR-08	Relocated 10m S.	Borehole relocated to attain ECW recommended distance form Water Vole borrows.
BH-PTR-09	Relocated 4m S.	Borehole relocated to attain ECW recommended distance form Water Vole borrows.
BH-PTR-21	Relocated N of drainage ditch	Borehole relocated to attain ECW recommended distance from Water Vole borrows.
BH-PTR-23	Revisited to redrill with a Window Sample rig.	Revisited to obtain UT100 samples of shallow soils using percussive drive methods (see Section 3.2.2). UT100s at BH-PTR-23A could not be obtained due to damaged UT100 equipment resulting in further revisit (BH-PTR-23B).
BH-PTR-24	Redrilled to 15m (BH-PTR-24A)	DS runs from the initial borehole were drilled to confirm UT100 sampling depths. These DS runs suffered frost damage and the BH was redrilled to obtained DS runs to 15m bgl (BH-PTR-24A).

Location	Adjustment / Variation	Rationale
BH-PTR-26	Revisited to redrill with a Window Sample rig.	Revisited to obtain UT100 samples of shallow soils using percussive drive methods (see Section 3.2.2). UT100s at BH-PTR-26A could not be obtained due to damaged UT100 equipment resulting in further revisit (BH-PTR-26B).
BH-PTR-27, BH-PTR-28 and CPT-PTR-02	Relocated N	Borehole relocated to attain ECW recommended distance from drainage ditch / Water Vole borrows.
BH-PTR-28	Revisited to redrill with a Window Sample rig.	Revisited to obtain UT100 using percussive drive methods (BH-PTR-28A).
BH-PTR-32	Revisited to redrill with a Window Sample rig.	Revisited to obtain UT100 samples of shallow soils using percussive drive methods (see Section 3.2.2). UT100s at BH-PTR-32A could not be obtained due to damaged UT100 equipment resulting in further revisit (BH-PTR-32B).
BH-PTR-36	Revisited to redrill with a Window Sample rig.	Revisited to obtain UT100 using percussive drive methods (BH-PTR-36A) – see Section 3.2.2.
BH-PTR-39	Revisited to redrill with a Window Sample rig.	Revisited to obtain UT100 samples of shallow soils using percussive drive methods (see Section 3.2.2). UT100s at BH-PTR-39A could not be obtained due to damaged UT100 equipment resulting in further revisit (BH-PTR-39B).
BH-PTR-43	Relocated twice due to a concrete obstruction at 1.30m bgl.	BH-PTR-43B (2m NE) cleared the obstruction.
BH-PTR-44	Relocated due to a concrete obstruction at 1.30m bgl.	BH-PTR-44A (1m NE) cleared the obstruction.
BH-PTR-45	Borehole terminated at 2.65m bgl on encountering visual evidence of contamination.	BH redrilled (BH-PTR-45A) in larger diameter (150mm) casing to enable aquifer protection measures.
BH-TH-09	Redrilled (see BH-TH-09A)	BH redrilled due to poor core recovery and omission of the variable head test.
CPT-PTR-05 CPT-PTR-06 CPT-OBC-05	Additional locations	Undertaken within affordable shift time for additional lateral coverage.
CPT-OBC-02	Re-located 20m East	Location adjusted on MML instruction.
TP-PTR-01	The scheduled excavation and in-situ assessment (plate load test) were cancelled.	Cancelled due to access constraints and risks associated with surcharging the drainage channel.
TP-PTR-24	Re-located 8m SW (TP-OBC-03A)	Relocated due to concrete obstruction / possible service at 0.90m bgl
TP-HRS-03	Re-located 15m E. The trial pit was also re-excavated (TP-HRS-03A).	Induced CAT signal detected within 8m of the specified position (along the route of the possible service encountered in TP-PTR-24). The specified position was also near to the kerb line. Re-excavated to repeat soakaway testing using a greater volume of water (TP-HRS-03A) – see Section 3.2.6.

Location	Adjustment / Variation	Rationale
TP-HRS-04	Re-located 7m E	Induced CAT signal detected within 5m of the specified position (along the route of the possible service encountered in TP-PTR-24).
DCP-HRS-01	Relocated 7m E.	Specified location near to the highways boundary and kerb line. Induced CAT signal detected within 5m of the specified position (along the route of the possible service encountered in TP-PTR-24).
DCP-HRS-02	Re-located 9m E.	Induced CAT signal detected within 6m of the specified position (along the route of the possible service encountered in TP-PTR-24).
DCP-HRS-04	DCP from GL only. Re-located 3m E	Induced CAT signal detected within 1m of the specified position (along the route of the possible service encountered in TP-PTR-24).
DCP-HRS-05	Re-located 7m E	Induced CAT signal detected within 6m of the specified position (along the route of the possible service encountered in TP-PTR-24).
TP-OBC-03	Re-excavated (TP-OBC-03A)	Re-visited after plate load test to complete excavation.
TP-OBC-11	Inspection pit / DCP only.	
TP-HWS-02	Not undertaken or log mislaid.	
Various locations	DCP Testing records were mislaid for TP-PTR-22, TP-PTR-32, TP-PTR-33, TP-HRS-02, DCP-HRS-08	DCP Testing records mislaid (identified post demobilisation).
Plate Load Testing	Specification adjusted (see Section 3.2.3)	The specification for plate load testing resulted in test periods extending beyond the working shift. The specification was therefore adopted to confine testing periods.

Exploratory hole locations were surveyed to Ordnance Datum as indicated on the Exploratory Hole Location Plans provided as Appendix A.

3.2 METHODOLOGY

Investigations were undertaken in broad compliance with the specification and to BS EN 1997-2:2007 incorporating corrigendum June 2010. A summary of activity specific methodology employed is provided in the following sections.

3.2.1 Setting Out

Exploratory hole locations were set out using a pole mounted global navigation satellite system (GNSS) receiver and recorded as Ordnance Survey (OS) (Newlyn) coordinates and elevation to an accuracy of ±100mm (easting and northing). Where minor adjustments to exploratory hole locations were required (see Table 3), the new location was taped to the originally surveyed location, and levels were extrapolated.

3.2.2 Boreholes

Boreholes were drilled using the following drilling rigs.

- Beretta T46 with a tracked compressor (R1)
- Beretta T41 with a mounted compressor (R2)
- Massenza M13 (R3)
- Beretta T59 with a wheeled compressor (R4)

The following down-hole equipment was used to obtain samples and undertake in-situ testing.

- Dynamic sampling (DS) – 1.00 and 1.50m lengths of 131mm OD & 101mm ID stainless high-tensile sample barrels (DS116 and T6-131DS) with a case-hardened cutting shoe and internal clear HDPE liners to obtain 101mm diameter dynamic samples.
- Rotary coring (RC) - triple-tube to obtain 1.5m long, 101mm dimeter core samples (T6131) or S-Geo bor wireline with HDPE liners.
- 150 to 200mm (T2 101 and T6 131) diameter casing.
- Standard Penetration Testing (SPT) hammer.
- UT100 sampler.

After non-intrusive service clearance procedures were implemented (scanning with a cable avoidance tool (CAT), and service constraints plans were checked, an inspection pit was hand excavated to a depth of 1.20m bgl.

Drilling was then typically commenced as a dynamic sample run (DS), or in many locations as a UT100 sample or SPT, prior to progression with DS. On completion of each run DS run, UT100 or SPT, casing was advanced, and the borehole was purged using air-mist (using an Atlas Copco 186 compressor).

The instructed change from dynamic sampling to rotary coring was based on the conditions observed during the drilling, and typically when drilling operatives reported lower rates of DS penetration, or SPT N values of

greater than 25 were recorded, or the supervising engineers confirmed the recovery of structured chalk within the base of the DS run. In local areas, at deeper levels when RC recovery was poor, RC was reverted to DS.

After poor core recovery was noted in the West Melbury Marly Chalk Formation, the flush medium was switched from air-mist to water with the aim of improving recovery at BH-PTR-08 and BH-PTR-09.

The depth of the DS / RC switch and flush medium is recorded on each engineering log.

Borehole locations are indicated on the drawings provided as Appendix A, and as OS coordinates indicated on the engineering logs. A summary of encountered conditions is provided in Section 4.1. Detailed descriptions of the conditions encountered are presented on the engineering logs (Appendix C1).

3.2.3 UT100 Sampling

Undisturbed sample (UT100) depths were discussed and confirmed on site during the progression of the BH and depths were targeted to obtain samples from fine soil horizons within the superficial deposits. Whilst R3 adopted a standard drop 63.5kg drop weight to percussively drive the UT100 at BH-PTR-03A, the other rigs (R1, R2 and R4) obtained UT100 samples using direct push.

At many locations, due to the variable composition of the near surface soils, which included a variable coarse soil component, UT100 driving was assisted by the hydraulic hammer. This was noted as non-compliant methodology by the supervising engineer.

When the query was raised, the drilling contractor reported that UTs at BH-PTR-20, BH-PTR-22, BH-PTR-23, BH-PTR-25 and BH-PTR-27 had been obtained with assistance from the hammer.

For the avoidance of any doubt, and to provide further surety regarding the integrity of the samples, MML instructed revisits to various locations to obtain UT100 samples using a window sampling rig and standard drop weight methods. These locations are listed in Table 3.

3.2.4 Recovery

In general, to optimize recovery, BHs were commenced using DS and progressed to depths where structured chalk was considered likely to be present based on insitu observations (e.g. SPT N and the presence of fragments of structured chalk in DS runs). Where structured chalk was considered likely the drilling method was switched from DS to rotary coring (RC) using either air-mist or water flush.

Due to the variable soil profile and changeable conditions across the site, the percentage of core recovery (both TCR% and SCR%) was often influenced by the drilling methodology adopted. Given the locally undulating depth of weathering grades and composition, an adaptive approach was required to ensure the most effective methodology was selected to maximize the recovery. In practice a multitude of factors impacted both DS and RC recovery and these factors had a variable degree of influence in local areas across the site.

Following observations made during core logging and further discussion with the drilling contractor, the mechanisms and conditions that are thought to have DS impacted recovery are summarised as follows.

- **Blow out** (DS) – prior to advancement of DS runs, BHs were purged using air-mist flush. During purging, loose coarse soils and low consistency fine soils are susceptible to minor blow out, particularly after disturbance from SPT, and unless reduced recovery coincided with evidence of dislocation, blow out is the most likely and prevalent mechanism for the reduction in DS recovery and has been identified in DS runs from all areas of the site in various units and compositions.
- **Sample loss –** significantly reduced recovery was prevalent in DS runs recovered from zones of structureless chalk, particularly from Grade Dm chalk below the water table. This occurrence is considered to be typical of DS recovery in loose coarse soils, e.g at the transition between the River Terrace Deposits and the structureless chalk, particularly where SPT N is very low, indicating very loose (where coarse soils are present), fluid or even **voided** conditions, and results from either blow out of material, or sample loss from the base of the run where the core catcher is unable to retain very loose or fluid soils. Soils are disturbed during advancement, and potential for core loss is therefore exasperated by lubricating groundwater, which is often evidenced by residue / striations in the vacant section of the core liner. Evidence of dislocation typically occurs at the top of the run and is suggestive of downward slippage of the sample and possible loss from the base of the run.
- **Sample gain –** where DS liners show evidence of residue and striations within the section of no recovery (and it has been assumed that downward dislocation of the sample has potentially occurred) and where anomalous materials are noted in the run below, there is potential for sample gain in the subsequent DS run to have occurred. It is noted that although purging of BHs prior to commencement of each DS run formed part of the drilling methodology, disturbance from SPT / UT100 prior to casing advancement, may in some locations, have resulted in minor collapse and gain from above.
- **Compression** – organic soils were prevalent in near surface alluvial soils, particularly in central areas of the site between BH-PTR-20 and BH-PTR-44, and most notably in BH-PTR-43B and BH-PTR-44A where a peat horizon overlain by a thick layer of Made Ground was encountered. Presence of organic rich soils often coincided with reduced DS length, and in addition to potential for blow-out during purging and sample loss, where organic soils are present, compression during DS sampling is also considered a likely factor in reduced DS recovery.
- Potential lateral compression of loose coarse soils has also been considered as a potential mechanism for reduced recovery, particularly where soils are very coarse and loose, and the DS liner simply pushes clasts / cobbles aside rather than capturing them within the DS run.
- In some instances, gravel or cobbles of flint or high-density chalk clasts have also been noted at the base of DS runs of partial or minimal recovery, possibly indicated blockage of the DS run prior to progression into underlying lower strength materials.

In addition to the above, the following scenarios, which are specific to RC, are considered as potential mechanisms for reduced recovery.

- **Blow out** (RC) **–** blow out is prevalent at the top of each run due to the disturbance and loosening caused during air-mist purging prior to the commencement of each run. These zones of reduced recovery are typically of increased extent where SPTs have been undertaken prior to purging. This often presents as a 100 to 450mm thick zone of non-intact chalk gravel at the top of each core run,

with reduced % recovery suggestive of the blow out of fines generated during the SPT or from disturbance during the previous core run.

- Reduced RC recovery is prevalent where RC runs are progressed into **structureless** / weak / low consistency chalk from structured or stronger chalk lying above. Horizons of calcified / lithified structureless chalk, or flint rich horizons, which may have presented high SPT N values or reduced RC penetration rates, which initially informed the decision to switch to RC, then deteriorated below the water table into Grade Dm and Dc in some locations, resulting in blowout. This occurrence was notable in BH-PTR-26, where drilling was reverted back to DS and this improved recovery.
- To maintain productivity, adjustments to the dynamic programme resulted in rigs operating in proximity. BH-PTR-31 was commenced shortly after commencement of BH-PTR-32 and drilling progressed in tandem. Bubbling of the ponded arisings around BH-PTR-32 confirmed the lateral penetration of the air-mist flush, which possibly also resulted in disturbance and localized blow out of fines within the ground around the borehole. This mechanism is a possible factor influencing the reduced recovery in BH-PTR-31 and may also have occurred in other areas, e.g. in OBC where boreholes were also located in proximity.
- With reference to C574[ref 6] and Mortimore 2021[ref 7], non-intact zones are often reflective of various attributes of the chalk itself, and based on observations of the core, the following characteristics are likely to have given rise to zones of non-intact core and the associated reduced recovery resulting from blowout of brecciated material.
    - Zones of potentially **intraclastic chalk** noted in both the Hollywell Nodular Chalk Formation and the Zig Zag Chalk Formation presented as relatively high-density chalk clasts in lower density matrix or matrix with a higher marl content (e.g BH-OBC-08 from 10.85m bgl to 15.00m bgl where nodules / clasts comprised mytilid fossils). These zones were observed both within intact sections of core as chalk conglomerate, and as non-intact subrounded and rounded chalk gravels with a residual plastic marly matrix, often associated with reduced recovery attributable to possible blow out of the weaker matrix. Intraclastic zones did not typically coincide with low SPT N values, and therefore present useful markers of zones of potentially nodular chalk with a high-density variation, or chalk with a relatively high marl content, occurring as high frequency seams or flasar marls.
    - Non-intact zones often coincided with **marl seams** which occurred as thin discrete seams within the Hollywell Nodular Chalk Formation, and as more graded marl horizons within the Zig Zag Formation. The core surrounding these seams often showed evidence of coning or blow out, suggesting that turning and core disturbance had occurred during drilling. Other sections showed no clear evidence of drilling induced disturbance surrounding the marl, suggesting that higher FIs or prevalence of non-intact zones could be in-insitu and associated with the marl seam itself (e.g through expansion of the marl or from increased weathering due to perched water above the seam).

[6] Ciria 574, Engineering in Chalk, 2002
[7] Quarterly Journal of Engineering Geology and Hydrogeology, Chalk: All we need is a fracture log!, Rory N. Mortimore, May 2021

- Non-intact zones coincided with **discontinuities**, and in addition to the turning and brecciation noted along bedding planes, brecciation also coincided with discontinuity intersections and conjugate sets, which often showed greater prevalence near to marl seams.

In summary, to a variable respective degree, core recovery is likely to have been impacted by a combination of the local drilling methods adopted, and the in-situ characteristics of the chalk.

A detailed review of the mechanisms involved is beyond the scope of this factual report, and the potential for involvement is therefore indicated as commentary within the engineering log descriptions (Appendix C1) as 'possible', 'probable' or 'likely' factors impacting core recovery.

Where drilling induced disturbance or recovery has obscured the fracture index (FI), either FI and '?' is indicated or the NI (Non-Intact) is indicated depending on the level of confidence attained.

3.2.5 Trial Pits

Trial pits were excavated using either a backhoe excavator (JCB ECO or similar), or a Hitachi ZX210 20-Tonne tracked excavator. The tracked machine also provided kentledge for the plate load testing. Excavation was carried out using 600mm and 1000mm wide toothless buckets, and where they did not refuse or display signs of significant signs of instability (as indicated on the trial pit logs), they were progressed to the specification depth.

Trial pit locations are indicated on Figure reference: B025563-TTE-00-XX-DR-U-0002-P01 Site Investigation Layout Plan (Sheets 1 to 13 inclusive, Appendix A), and as OS coordinates indicated on the engineering logs. A summary of encountered conditions is provided in Section 4.1 and detailed on the engineering logs presented in Appendix C2

3.2.6 Soil Infiltration Testing

Soil infiltration testing was undertaken at the specified locations in broad occurrence with BRE365. Prior to test commencement, on reaching the required test depth, the base of the excavation was squared and levelled to the degree achievable with the excavator and potable water was introduced from a 80mm outlet from either a 1000litre water bowser, or where infiltration rates were high, to achieve an greater inflow, using a 5000litre water bowser. Both methods typically achieve an inflow rate of approximately 500ltrs in 2minutes. Infiltration rates (*f*) are summarised in Section 4.2.2 and data is presented on the sheets included as Appendix F.

3.2.7 Dynamic Cone Penetrometer (DCP)

Dynamic cone penetrator (DCP) testing was undertaken from ground level at various machine excavation locations ('TP' ref. where scheduled) and adjacent to 1.20m deep hand excavated inspection pits ('DCP' ref.).

The tests were undertaken using a standard Transport and Roads Research Laboratory (TRRL) specification DCP probe to drive a 20mm diameter 60° cone using an 8kg weight dropped from a height of 575mm.

DCP locations are indicated on Figure reference: B025563-TTE-00-XX-DR-U-0002-P01 Site Investigation Layout Plan (Sheets 1 to 13 inclusive, Appendix A, and as OS coordinates indicated on the engineering logs.

The California Bearing Ratio (CBR) derived from these tests is presented in the tables included in Appendix G. CBR has been calculated for layers displaying discernible uniform rates of penetration (blows /10mm) using the TRRL standard relationship: **$Log_{10}(CBR) = 2.48-1.057.Log_{10}(mm/blow)$.**

3.2.8 Plate Load Testing

Plate load testing was carried out using 455mm diameter plates in accordance with BS 1377-9 using a 20-Tonne excavator to provide a kentledge of approximately 200 to 250kPa at 31No trial pit locations. Settlement and load were measured using a digital gauge and initially incrementally loaded until the maximum travel of the dial gauge was achieved. Due to the slow and continuous rates of settlement at higher load increments, which resulted in testing periods extending beyond the working shift, the specification was adjusted by the supervising engineer to the increments set out in Table 4. Settlements recorded are summarised in Section 4.2.1 and detailed on the plate load test logs included as Appendix E.

Table 4 Plate Load Stages (specification adjustment)

Increment	Stage	Load (kPa)	Holding Time (minutes)
1	Load	30	10
2	Load	60	10
3	Load	90	10
4	Load	120	10
5	Unload	150	10
6	Unload	75	10
7	Reload	0	10
8	Reload	50	10
9	Reload	100	10
10	Reload	150	30 - with test specific adjustments based on stage behavior
11	Load	200	30 - with test specific adjustments based on stage behavior
12	Load	250	30 - with test specific adjustments based on stage behavior
13	Unload	125	10
14	Unload	0	10

3.2.9 Cone Penetration Testing (CPT)

Cone Penetration Tests (CPTs) were undertaken through the base of hand excavated inspection pits using a 20 tonne track-truck mounted unit. The CPT cone comprised a10 cm^2 projected cone tip area with 150 cm^2 friction sleeve area. The CPT report (Appendix D) provides a description of algorithms applied to derive various parameters and the associated empirical relationship with the soil types is presented on the CPT logs presented in Appendix D.

CPT locations are indicated on Figure reference: B025563-TTE-00-XX-DR-U-0002-P01 Site Investigation Layout Plan (Sheets 1 to 13 inclusive, Appendix A), and as OS coordinates indicated on the engineering logs.

3.2.10 Soil Survey

To inform the schemes soil management strategy, Tt provided labour and equipment to undertake the intrusive work required to inform the Soil Resource Survey (SRS) and Agricultural Land Classification Surveys (ALC).

The SRS and ALC intrusive work comprised hand augering to a depth of 1.20m bgl at approximately 100m intervals along the PRT and included hand excavated inspection pits and selected locations. This work was supervised by the MML Soil Scientist who recorded the physical properties of the soils and obtained samples for analysis, which were submitted to a laboratory and scheduled for testing directly by MML. This information has been reported separately by others.

The hand auger positions are indicated on Figure reference: B025563-TTE-00-XX-DR-U-0002-P01 Site Investigation Layout Plan (Sheets 1 to 13 inclusive, Appendix A) as 'SS' referenced positions.

3.2.11 Borehole Installations

Dual purpose land gas and groundwater monitoring standpipes were installed within boreholes as instructed by the supervising engineer.

Installations were constructed using slotted 50mm diameter HDPE standpipe with a 325µm filter wrap and 10mm dia. pea-shingle surround. Sharp sand was introduced at the top of the filter zone to prevent mixing of the bentonite introduced above the response zone. The installations were finished at ground level with gas taps and concreted upstanding covers surrounded by a timber enclosure.

Installation details are provided on the engineering logs and summarised in Table 5.

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Table 5 Summary of Borehole Installations

Location	Response Zone Depth (m bgl)		Response Zone Depth (m AOD)		Unit
	Top	Base	Top	Base	
BH-BP-01	1.00	1.80	17.16	16.36	Alluvium
BH-OBC-01	1.00	3.50	25.71	23.21	River Terrace Deposits
BH-OBC-04 S	1.00	3.00	24.46	22.46	River Terrace Deposits
BH-OBC-04 D	13.00	19.00	12.46	6.46	Hollywell Nodular Chalk Formation
BH-OBC-06	7.00	11.00	18.55	14.55	Hollywell Nodular Chalk Formation & Zig Zag Chalk Formation
BH-OBC-07 S	3.00	10.00	23.32	16.32	Hollywell Nodular Chalk Formation
BH-OBC-07 D	20.00	29.00	6.32	-2.68	Zig Zag Chalk Formation
BH-OBC-11 S	14.00	17.00	11.41	8.41	River Terrace Deposits
BH-OBC-11 D	1.00	2.50	24.41	22.91	Hollywell Nodular Chalk Formation
BH-OBC-12	17.00	20.00	8.74	5.74	Hollywell Nodular Chalk Formation
BH-OBC-15	24.00	29.00	2.47	-2.53	Zig Zag Chalk Formation
BH-PTR-02 S	1.20	2.20	13.62	12.62	Alluvium & West Melbury Marly Chalk Formation
BH-PTR-02 D	4.50	10.00	10.32	4.82	West Melbury Marly Chalk Formation
BH-PTR-04	2.00	6.00	11.87	7.87	Alluvium & West Melbury Marly Chalk Formation
BH-PTR-06	8.00	15.00	5.81	-1.19	West Melbury Marly Chalk Formation
BH-PTR-08 S	1.00	2.50	12.94	11.44	Alluvium & West Melbury Marly Chalk Formation
BH-PTR-08 D	10.00	15.00	3.94	-1.06	West Melbury Marly Chalk Formation
BH-PTR-10	1.00	5.00	12.98	8.98	Alluvium & West Melbury Marly Chalk Formation
BH-PTR-12	7.00	10.00	8.46	5.46	Alluvium & West Melbury Marly Chalk Formation
BH-PTR-13	1.50	6.00	15.44	10.94	Zig Zag Chalk Formation
BH-PTR-14	4.50	10.00	14.11	8.61	Zig Zag Chalk Formation
BH-PTR-16	1.00	3.50	37.80	35.30	Hollywell Nodular Chalk Formation (Melbourn Rock Member ?)
BH-PTR-18	2.00	5.00	18.36	15.36	Zig Zag Chalk Formation
BH-PTR-19	1.50	5.00	17.21	13.71	River Terrace Deposits

Location	Response Zone Depth (m bgl)		Response Zone Depth (m AOD)		Unit
	Top	Base	Top	Base	
BH-PTR-21	1.00	4.00	17.41	14.41	River Terrace Deposits
BH-PTR-27	3.00	5.50	15.37	12.87	River Terrace Deposits
BH-PTR-30	15.00	22.00	2.38	-4.62	Zig Zag Chalk Formation
BH-PTR-31	5.00	11.00	12.20	6.20	Zig Zag Chalk Formation
BH-PTR-33 S	1.00	4.50	16.47	12.97	Alluvium & River Terrace Deposits
BH-PTR-33 D	22.00	28.50	-4.53	-11.03	Zig Zag Chalk Formation
BH-PTR-35	1.00	3.00	17.41	15.41	River Terrace Deposits
BH-PTR-36	1.00	3.50	17.42	14.92	Alluvium
BH-PTR-39	12.00	14.50	6.78	4.28	Zig Zag Chalk Formation
BH-PTR-41 S	1.00	2.30	18.83	17.53	Made Ground & Alluvium
BH-PTR-41 D	5.00	10.50	14.83	9.33	Zig Zag Chalk Formation
BH-PTR-42 S	1.00	1.90	19.29	18.39	Made Ground
BH-PTR-42 D	3.50	10.00	16.79	10.29	Alluvium & Zig Zag Chalk Formation
BH-PTR-43B S	1.00	3.00	19.44	17.44	Made Ground & Grade Dm Chalk
BH-PTR-43B D	5.00	10.00	15.44	10.44	Zig Zag Chalk Formation
BH-PTR-45A	5.00	10.00	21.85	16.85	Hollywell Nodular Chalk Formation
BH-TH-01	6.00	12.00	23.00	17.00	Hollywell Nodular Chalk Formation & Newpit Chalk Formation ?
BH-TH-03	1.00	3.50	28.44	25.94	River Terrace Deposits & Hollywell Nodular Chalk Formation
BH-TH-05	1.00	2.00	28.32	27.32	River Terrace Deposits
BH-TH-06	1.00	8.00	30.65	23.65	Hollywell Nodular Chalk Formation
BH-TH-08	1.10	4.00	33.71	30.81	River Terrace Deposits, Lowestoft Formation ? & Hollywell Nodular Chalk Formation

S – Shallow Installation, D – Deep Installation

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3.2.12 Monitoring and Sampling

Inclusive of CE015, which detailed requirements for extended groundwater monitoring over the 8-month period post ground investigation to March 2022, the following monitoring was undertaken.

- Well development on completion of the intrusive investigation.
- 2No low flow water sampling rounds with water quality measurement undertaken two and six weeks post well development.
- 4No gas monitoring rounds at weekly intervals post well development.
- 8No water level and quality monitoring visits undertaken at monthly intervals.

3.2.13 Well Development, Groundwater Sampling and Water Quality Monitoring

Prior to monitoring, well development was undertaken via the purging of 3 x the volume of the monitoring wells using peristaltic pumps (where BH depth is less than 9m) and bladder pumps (where BH depths is greater than 9m).

On stabilisation of the following water quality measurements (WQM), recorded at 3min intervals via Aquatroll 400, water samples were then obtained via low-flow sampling.

- pH (+/- 0.1),
- Temperature °C (+/- 0.5)
- Specific Conductivity µS/cm (+/-3%)
- Dissolved oxygen (%)
- Redox Potential (mV)
- Observations of purge water and purge water volumes recorded during well development are included in Appendix H.

WQM are included as Appendix I. These parameters were also recorded in-situ using submersible instruments during return water monitoring visits as part of CE014 (included in Appendix H).

3.2.14 Ground Gas Monitoring

Sample head space was checked for volatile organic compounds (VOCs) using a Photo Ionisation Detector (PID) during the collection of shallow soil samples. PID measurements are indicated on the engineering logs (Appendix C).

4No return gas monitoring visits have been carried out between the 11th and 14th May 2021 (Round 1), between the 18th and 26th May 2021 (Round 2 and 3), and on the 4thJune 2021 (Round 4) to monitor VOCs and record the following parameters using a GA5000 Gas Analyser.

- Atmospheric pressure (mB)
- Gas flow rates (liters/hr)
- Methane CH_4 (% Volume)
- Carbon Dioxide CO_2 (% volume)
- Oxygen O_2 (% volume), CO (ppm)
- Hydrogen Sulfide H_2S (ppm)

Landgas monitoring results are included as Appendix H and summarised in Section 3.3.12.

3.2.15 Laboratory Environmental Assessment

The environmental chemistry of soil samples collected during the intrusive investigations and groundwater samples collected during return monitoring visits was investigated by specialist chemical analysis of selected samples, scheduled by MML, and carried out by ALS Laboratories who are UKAS and MCERTS accredited for the range of chemical analyses.

The scheduled testing suites are detailed with the specification and the testing undertaken is summarised in Table 6.

Table 6 Summary of Laboratory Environmental Assessment

Test Suite	Determinants	No. Tests
MML Comprehensive Soil Suite	Heavy Metals, BTEX, Phenols, PAH, TPH, VOC and Asbestos Screen	138
MML Comprehensive Leachate Suite	Heavy Metals, Phenols, NH_3-N, $CaCO_3$ (Hardness) and Dissolved Organic Carbon	62
MML Comprehensive Water Suite	Heavy Metals, Phenols, PAH, TPH, VOC, Alkalinity (Bicarbonate) and Dissolved Organic Carbon	59
MML Waste Acceptance Criteria	Heavy Metals, TOC, Loss on Ignition, BTEX, PCB (7 congeners), Mineral Oil (10-C40), PAH, Fluoride, Chloride, Phenol Index, pH	16

BTEX - benzene, toluene, ethylbenzene and xylene, PAH – polyaromatic hydrocarbons, TPH – total petroleum hydrocarbons, VOC – Volatile Organic Compounds, TOC - Total Organic Carbon, PCB - polychlorinated biphenyl

Samples were submitted to the laboratory during the investigation works in daily batches. Results and laboratory test certificates are provided in Appendix K1 and K2

3.2.16 Laboratory Geotechnical Assessment

Laboratory geotechnical testing of soil samples was scheduled by MML and undertaken by PSL in accordance with their UKAS accreditation. Testing completed is summarised in Table 7.

Laboratory test certificates are provided in Appendix J.

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Table 7 Summary of Laboratory Geotechnical Assessment to date (10.11.21)

Test	Standard	No. Tests
Moisture Content	BS 1377: Part 2 : Clause 3.2 : 1990	154
Atterberg Limits	BS EN ISO 17892-12:2018	133
Moisture Content of Rock	BS 1377: Part 2 : Clause 3.2 : 1990	380
Dry density and saturation moisture content for chalk	BS 1377 : Part 2 : Clause 3.3&7.3 : 1990	256
Particle distribution by wet sieving including SHW : Clause 600	BS EN ISO 17892-4:2016, clause 5.2	104
Sedimentation by hydrometer	BS EN ISO 17892-4:2016, clause 5.3	58
Organic matter content	BS 1377: Part 3.2: 1990	22
Geotechnical Chemistry - BRE SD1 Suite A (Table D1 inclusive of triggered determinants)	BRE SD1 2005, BS1377: Part 3: 1990	147
One-dimensional consolidation properties	BS EN ISO 17892-5 : 2017	2
Undrained strength (100mm dia) in triaxial compression	BS EN ISO 17892-8:2018	3
Uniaxial compressive strength	ISRM : Parts 1 & 2 : 2007	54
Single measurements of point load strength on core sample	ASTM / ISRM : 2007	435
Chalk crushing value	BS1377 : Part 4 Clause 6.4 : 1990	6
Extrude, split, photograph, describe structure	BS5930	19
LA Coefficient	SHW : 600	4
Direct Shear Strength (300mm shear box)	SHW : 636 : Part 2	5
Compaction (vibrating hammer)	BS1377 : Part 4 : Clause 3.7 : 1990	6
Geotechnical Chemistry	SHW : 600 : Clauses 601-17	5

4.0 GROUND CONDITIONS ENCOUNTERED

4.1 SUMMARY

The encountered ground conditions compared well to those anticipated from the published information and previous investigations, and in summary comprised Made Ground / Topsoil, Superficial Deposits (Alluvium, River Terrace Deposits) and locally, the Lowestoft Formation, over various units of the Chalk Groups in deepening succession.

General notes and characteristics of the units identified on the engineering logs are summarised in Table 8. Detailed rock and unit descriptions, together with depths, thickness and TCR, RQD and FI are provided on the engineering logs (Appendix C1).

A photographic record of the DS, RC, inspection pits and trial pits is provided in Appendix M.

Table 8 Summary of Characteristics and Distribution of the Units Encountered

Unit	Summary Characteristics and Distribution
Made Ground – Topsoil	Most exploratory hole locations were commenced in arable fields and surface soils typically comprised predominantly fine soils with a lessor sand and gravel content below recently planted or established crops or grass. Occasional anthropogenic inclusions were noted in local areas, including plastic, ceramic and concrete fragments. Trace chrysotile (asbestos) fibers were confirmed to be present in a sample of topsoil recovered from a depth of 1.00m bgl at BH-PTR-24.
Made Ground	Obvious signs of anthropogenic influence were noted to deeper levels in local areas, notably in North Farm (TP-PTR-32 to TP-PTR-37 inclusive, and BH-PTR-43A, BH-PTR-43B, BH-PTR-44, BH-PTR-44A and BH-PTR-45) where inclusions of brick, concrete, asphalt and fused ash, possibly associated with the former rail line, were noted to depths of up to 2.65m bgl.
Alluvium	Alluvial soils were prevalent across the site and generally thicker towards the river crossings and drainage ditches. The deposit was highly variable in composition, and typically comprised low-consistency fine soils, with organic rich and peat horizons, often with predominantly coarse pockets and layers, which have typically been defined as alluvium where they grade back into predominantly fine soils at deeper levels. Shell fragments (possibly freshwater snails) and organic odors were also noted. The highly variable composition of the Alluvium, particularly in central areas of the site, could possibly be attributable to the heterogeneity of likely local parent materials, such as the Lowestoft Formation (glacial till). Further evidence of possible glacial influence is presented by locally polymict zones, where, in addition to flint, limestone and sandstone gravels were also recorded.
River Terrace Deposits	The River Terrace Deposits were also noted in all areas of the site, and typically comprised sandy flint gravel and to a lesser extent, layers of sand. Layers / pockets of fine soil were also recorded, particularly towards the base of the unit, within the transition zone with the underlying chalk units, where pockets of light orangish brown clay or silt of chalk occur as remnants of the weathered chalk horizons. At deeper levels within the River Terrace Deposits, flints were often less fragmented, nodular and rinded (indicative of close association with the underlying chalk formations).

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Unit	Summary Characteristics and Distribution
Lowestoft Formation	The characteristically high-strength (stiff), predominantly fine, shallow soils encountered below the River Terrace Deposits in the N of the TH area, are distinguished from the more typical coarse soils of the River Terrace Deposits, are identified on the engineering logs as the Lowestoft Formation.
Hollywell Nodular Chalk / Newpit Chalk Formation Undifferentiated	Chronological biomarker fossils and established marker beds (Glynbourne Tubular Flints and the Guns Gardens Main Marl) indicative of the transition zone between the Hollywell Nodular Chalk Formation and the Newpit Chalk Formation have been tentatively identified within chalk recovered from the TH boreholes. Therefore, although the anticipated youngest chalk unit in this area comprises the Hollywell Nodular Chalk Formation, these markers suggest that the Newpit Chalk Formation could also be present as the youngest / shallowest units and potentially outcrops further N / W as part of a structural low. The engineering logs have therefore not attempted to differentiate these units within TH boreholes.
Hollywell Nodular Chalk Formation	The presence of characteristically weak to strong, low to medium density, off-white to white chalk, with discrete marl seams and flasar marls that displayed high contrast with the chalk, generally coincided with the anticipated lateral extent and depth of the Hollywell Nodular Chalk Formation. Established marker beds such as the Plenus Marls Member (interbedded chalk and marl), and the Melbourn Rock Member (hard off-white chalk with nodular chalk beds and flasar marls), along with biomarkers, were often found to occur at the anticipated base depth of this formation, the shallowing of which ties in with the southerly dipping succession. These characteristics were absent from BHs north of BH-PTR-16, where it has been assumed the underlying units outcrop in the N portion of the site.
Zig Zag Chalk Formation	The Zig Zag Chalk Formation was encountered from ground level in the N central area of the site, and below the Hollywell Nodular Chalk Formation, and was characteristically off-white, becoming light or pale grey chalk, with rhythmic gradational marl seams, and frequent intraclastic zones, typically occurring as off-white chalk clasts in a grey, occasionally marly matrix.
West Melbury Marly Chalk Formation	The West Melbury Marly Chalk Formation was encountered from ground level in the N area of the site, and below the Zig Zag Chalk Formation, and was characteristically grey, silty marl.

4.1.1 Groundwater

Groundwater strikes occurring during the formation of the boreholes are indicated on the engineer logs. Water levels recorded during the investigation are presented in Table 9.

Table 9 Groundwater Levels During the Investigation

Location	Base Depth (m bgl)	Depth to water (m bgl)								
		2.3.21	3.3.21	8.3.21	9.3.21	12.3.21	23.3.21	30.3.21	31.3.21	14.4.21
BH-OBC-01	3.55	-*	-*	-*	-*	2.7	2.97	2.88	-*	-*
BH-OBC-04	18.95	-*	-*	-*	-*	-*	1.59	1.46	-*	-*
BH-OBC-06	7.85	-*	-*	-*	-*	-*	2.10	1.88	-*	-*
BH-OBC-11	17.03	-*	-*	-*	-*	-*	1.58	1.45	-*	-*
BH-OBC-12	19.78	-*	-*	-*	1.75	-*	1.93	1.89	-*	-*
BH-OBC-15	29.2	-*	-*	3.11	-*	-*	3.10	3.06	-*	-*
BH-PTR-03A	6.045	-*	-*	-*	-*	-*	-*	-*	-*	1.320
BH-PTR-04	3.090	-*	-*	-*	-*	-*	-*	-*	-*	1.180
BH-PTR-07	14.275	-*	-*	-*	-*	-*	-*	-*	-*	0.760
BH-PTR08D	12.80	-*	-*	-*	-*	-*	-*	-*	-*	0.928
BH-PTR08S	2.180	-*	-*	-*	-*	-*	-*	-*	-*	1.015
BH-PTR-10	4.673	-*	-*	-*	-*	-*	-*	-*	-*	0.880
BH-PTR-12	9.545	-*	-*	-*	-*	-*	-*	-*	-*	2.210
BH-PTR-13	5.620	-*	-*	-*	-*	-*	-*	-*	-*	2.155
BH-PTR-14	10.055	-*	-*	-*	-*	-*	-*	-*	-*	3.870
BH-PTR-15	9.650	-*	-*	-*	-*	-*	-*	-*	-*	DRY
BH-PTR-16	3.270	-*	-*	-*	-*	-*	-*	-*	-*	DRY
BH-PTR-18	5.370	-*	-*	-*	-*	-*	-*	-*	-*	3.95
BH-PTR-19	4.18	1.935	1.940	1.926	-*	-*	-*	-*	-*	2.340
BH-PTR-21	4.505	1.407	1.420	1.440	-*	-*	-*	-*	-*	1.745
BH-PTR-27	5.05	0.805	0.815	0.802	-*	-*	-*	-*	-*	1.08
BH-PTR-30	21.75	-*	-*	-*	-*	-*	-*	-*	0.82	1.065
BH-PTR-31	11.07	-*	-*	-*	-*	-*	-*	-*	-*	1.00
BH-PTR-33D	28.1	-*	-*	-*	-*	-*	-*	-*	-*	1.175
BH-PTR-33S	4.095	-*	-*	-*	-*	-*	-*	-*	-*	1.207
BH-PTR-35	2.285	-*	-*	-*	-*	-*	-*	-*	0.41	1.757
BH-PTR-36	3.555	-*	-*	-*	-*	-*	-*	-*	0.8	1.275
BH-PTR-39	11.79	-*	-*	-*	-*	-*	-*	-*	0.55	0.975
BH-PTR-43D	3.365	-*	-*	-*	-*	-*	-*	-*	-*	0.540
BH-PTR-43S	8.135	-*	-*	-*	-*	-*	-*	-*	-*	1.635

D – Deep Installation, **S** – Shallow Installation, * - Denotes not monitored

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4.2 INSITU TESTING

4.2.1 Plate Load Testing

Plots of settlement recorded during plate load testing are included with the plate load test certificates in Appendix E. Settlements recorded at each loading stage together with the derived CBR are provided in Table 10.

Table 10 Summary of Plate Load Testing

Location	Test Depth (m)	Unit *	Maximum Deflection (mm)	K_{762} (kNm²/mm)	Derived CBR[8]
TP-PTR-02	0.00	Grade Dm	4.57	39.0	5.5
TP-PTR-05	0.30	Made Ground - F	11.64	10.5	0.6
TP-PTR-06	0.50	Made Ground - F	24.9	5.4	0.2
TP-PTR-08	0.40	Made Ground - F	9.91	21.8	2.0
TP-PTR-09	0.45	Grade Dc	11.46	14.7	1.0
TP-PTR-12	0.45	Grade Dc	16.99	12.6	0.8
TP-PTR-16	0.40	Alluvium - F	8.03	47.8	7.9
TP-PTR-17	0.50	Grade Dc	20.72	13.1	0.80
TP-PTR-20	0.30	Grade Dc	8.95	50.0	8.5
TP-PTR-21	0.50	Grade Dc ?	15.50	7.6	0.3
TP-PTR-23	0.50	Alluvium - F	16.88	18.1	1.5
TP-PTR-24	0.45	Alluvium - F	18.18	19.2	1.6
TP-PTR-28	0.50	Grade Dc	7.15	69.0	14.8
TP-PTR-29	0.40	Grade Dc	2.90	124.9	41.4
TP-PTR-31	0.40	Made Ground - F	19.45	5.6	0.2
TP-PTR-32	0.40	Made Ground - C	5.30	35.1	4.6
TP-PTR-33	0.00	Made Ground - F	3.83	42.7	6.4
TP-PTR-34	0.00	Made Ground - F	11.05	16.5	1.2
TP-PTR-35	0.40	Made Ground - F	6.51	22.4	2.1
TP-PTR-38	0.30	Alluvium - F	2.70	63.7	12.9
TP-PTR-39	0.40	Alluvium - C	3.97	50.0	8.5
TP-PTR-40	0.40	Alluvium - C	12.05	20.2	1.8
TP-PTR-42	0.40	Alluvium - F	5.70	15.2	1.1
TP-PTR-43	0.32	Alluvium - F	4.23	33.5	4.2
TP-PTR-56	0.30	Alluvium - C	21.54	18.4	1.5
TP-OBC-03	0.50	Alluvium - F	14.71	8.9	0.4
TP-OBC-05	0.45	Grade Dc	4.73	34.8	4.5
TP-OBC-06	0.50	Grade Dc	4.69	38.4	5.4

[8] Design Manual for Roads and Bridges, Volume 7, Section 2: Chapter 4 Calculation of Equivalent CBR Value from Plate Bearing Test

Location	Test Depth (m)	Unit *	Maximum Deflection (mm)	K_{762} (kNm²/mm)	Derived CBR[8]
TP-OBC-08	0.50	Alluvium - F	19.30	77.0	17.9
TP-OBC-09	0.40	Grade Dm	3.99	39.7	5.4
TP-OBC-13	0.00	Made Ground - F	2.47	75.5	17.3

C – Denotes predominantly coarse soil, **F** – Denotes predominantly fine soil, **K_{762}** - modulus of subgrade reaction

4.2.2 Soil Infiltration Testing

A full record of soil infiltration testing is provided in Appendix F. Table 11 summarises the soil infiltration rates (*f*) obtained from tests where BRE365 compliant testing has been achieved.

Table 11 Summary of Soil Infiltration Testing

Location	Effective Test Depth (m)		Unit *	Soil infiltration rate (m/s)			
	T25 %	T75 %		Test 1	Test 2	Test 3	Average (*f*)
TP-HRS-03	>500ltrs added per test, 1m head not established in 2.90m deep trial pits due to high infiltration.		CHALK (Grade Dc)	NR	>2.4e-03	>3.82e-03	>3.11e-03
TP-HRS-03A			CHALK (Grade Dc)	>1.87e-03	>2.02e-03	>1.30e-03	>1.73e-03
TP-HRS-04			CHALK (Grade Dc)	>1.52e-03	>1.08e-03	>1.00e-03	>1.20e-03
TP-TH-02	2.00	2.75	CHALK (Grade Dc)	5.05e-05	5.06e-05	4.79e-05	4.96e-05
TP-TH-04	2.07	2.50	CHALK (Grade Dc)	1.85e-05	2.38e-05	1.72e-05	1.98e-05
TP-TH-06	2.35	2.85	CHALK (Grade Dc)	T50%/3hr	1.19e-05	2.63e-05	<2.63e-05
TP-TH-07	2.10	2.70	CHALK (Grade Dc)	1.11e-05	1.13e-05	NT	<1.12e-05
TP-TH-08	2.58	1.73	CHALK (Grade Dc)	4.01e-05	4.33e-05	4.33e-05	4.22
TP-TH-09	2.10	2.70	CHALK (Grade Dc)	T30%/3hr	T40%/7hr	NT	ND
TP-TH-11	2.67	3.00	CHALK (Grade Dc)	2.37e-04	2.32e-04	1.72e-04	2.13e-04
TP-TH-13	2.48	3.03	CHALK (Grade Dm)	1.69e-04	2.49e-04	2.32e-04	2.16e-04
TP-TH-14	2.53	1.81	CHALK (Grade Dm)	T50%/5hr	T65%/7hr	NT	ND

NR – No Head Established, **NT** – Test not carried out (due to time limitations), **ND** - Not determinable

4.3 MONITORING

4.3.1 Groundwater Monitoring

Water levels recorded during the 3No. return monitoring visits completed post ground investigations and the further 6No monitoring rounds completed as part of the extended monitoring programme (CE 015) as summarised below are presented in Table 12.

Post Ground investigation rounds

- Round 1: 10.5.21
- Round 2: 17 to 24.5.21
- Round 3: 3 to 4.6.21

CE 015 Extended monitoring rounds

- Round 4: 17 and 30.10.21
- Round 5: 13 to14.11.21
- Round 6: 18 to 19.12.21
- Round 7: 8 to 9.1.22
- Round 8: 26 to 27.2.22
- Round 9: 18 to 19.3.33

Table 12 Groundwater Levels During Return Monitoring

Location	Base Depth (m bgl)	Groundwater Depth (m bgl) / Round								
		1	2	3	4	5	6	7	8	9
BH-BP-01	1.92	-*	1.05	1.24	1.20	1.18	1.29	-*	-*	2.60
BH-OBC-01	3.12	Dry	Dry	Dry	Dry	Dry	DRY	-*	-*	DRY
BH-OBC-04D	18.77	2.26	2.41	2.80	3.79	3.50	3.76	2.74	2.74	2.60
BH-OBC-04S	2.4	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-OBC-06	7.46	2.68	2.96	3.22	4.34	4.06	4.23	3.24	3.24	3.08
BH-OBC-07D	28.33	3.46	3.7	3.99	5.09	4.83	5	4.09	4.09	3.92
BH-OBC-07S	9.52	3.11	3.34	3.63	4.68	4.38	4.58	3.65	3.65	3.49
BH-OBC-11D	20.16	2.44	2.65	2.91	4.23	3.96	3.99	2.97	2.97	2.85
BH-OBC-11S	2.32	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-OBC-12	19.27	2.72	1.98	3.27	4.59	4.31	4.35	3.33	3.33	3.23
BH-OBC-15	28.6	3.85	4.12	4.39	6.71	5.43	5.5	4.53	4.53	4.39
BH-PTR-02D	9.54	1.23	1.04	1.31	1.03	1.04	0.85	1.06	1.06	0.95
BH-PTR-02S	2.26	1.1	0.96	2.36	0.86	0.90	1.05	0.95	0.95	0.88
BH-PTR-03A	6.01	1.1	0.89	1.06	1.16	1.22	0.98	0.91	0.91	0.87
BH-PTR-04	2.76	0.9	0.62	0.78	0.80	0.81	0.76	0.64	0.64	0.52
BH-PTR-07	13.84	0.54	0.5	0.60	0.36	0.36	0.58	0.61	0.61	0.62
BH-PTR-08D	12.42	0.54	0.56	0.67	0.24	0.37	0.78	0.68	0.68	0.65

Location	Base Depth (m bgl)	Groundwater Depth (m bgl) / Round								
		1	2	3	4	5	6	7	8	9
BH-PTR-08S	1.75	0.57	0.61	0.73	0.39	0.42	0.79	0.76	0.76	0.68
BH-PTR-10	4.25	0.54	0.52	0.64	0.26	0.42	0.73	0.65	0.65	0.62
BH-PTR-12	9.26	1.92	1.99	2.08	1.73	1.78	2.11	2.01	2.01	1.97
BH-PTR-13	5.25	1.97	2.02	2.15	5.04	2.44	2.68	2.23	2.23	2.13
BH-PTR-14	9.63	3.68	3.71	3.86	4.15	4.19	4.48	3.97	3.97	3.87
BH-PTR-15	9.35	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-PTR-16	2.98	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-PTR-18	4.81	3.85	4.03	4.16	Dry	Dry	Dry	Dry	Dry	Dry
BH-PTR-19	3.81	2.32	2.36	2.50	2.82	2.85	3.07	2.46	2.46	2.34
BH-PTR-21	4.32	1.66	1.64	1.76	1.77	1.80	1.97	1.63	1.63	1.54
BH-PTR-27	5.11	0.84	0.81	0.99	0.88	0.91	1.13	0.87	0.87	0.79
BH-PTR-30	21.59	1.01	0.99	1.15	1.40	2.32	1.38	1.07	1.07	0.99
BH-PTR-31	11.76	0.85	0.84	0.91	1.09	1.04	1.13	0.88	0.88	0.82
BH-PTR-33D	27.65	0.94	1.04	1.16	1.21	1.16	1.29	1.02	1.02	0.97
BH-PTR-33S	3.7	1.05	1.06	1.22	1.23	1.16	1.26	1.04	1.04	0.98
BH-PTR-35	3.02	1.67	1.62	1.73	1.58	1.44	1.56	1.43	1.43	1.36
BH-PTR-36	3.1	0.13	0.92	1.13	0.93	0.65	0.74	0.69	0.69	0.60
BH-PTR-39	11.38	0.56	0.62	0.78	0.76	0.63	0.91	0.61	0.61	0.56
BH-PTR-41D	9.38	1.36	1.26	1.52	1.54	1.43	1.65	1.32	1.32	1.28
BH-PTR-41S	2.15	1.41	1.43	1.53	1.69	1.50	1.56	1.31	1.31	1.28
BH-PTR-42D	8.8	1.72	1.55	1.75	1.73	1.58	1.76	1.37	1.37	1.30
BH-PTR-42S	1.66	Dry	1.49	1.75	Dry	Dry	Dry	Dry	Dry	Dry
BH-PTR-43D	7.64	1.41	1.54	1.52	1.77	1.49	1.65	1.01	1.01	0.85
BH-PTR-43S	2.95	1.42	1.40	1.49	1.76	1.54	1.45	1	1.00	0.81
BH-PTR-45	9.69	5.9	5.89	5.98	5.88	5.69	5.95	5.62	5.62	5.57
BH-TH-01	11.24	5.46	5.82	6.18	7.44	7.14	7.31	6.23	6.23	6.03
BH-TH-03	4.15	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-TH-05	1.75	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-TH-06	6.4	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH-TH-08	4.57	-*	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry

D – Deep Installation, **S** – Shallow Installation, * - Denotes not monitored

4.3.2 Water Quality Monitoring

Groundwater parameters were monitored until they stabilized prior to groundwater sampling (see Section 3.2.12), due to the volume of data, this information is available in digital format only.

Return monitoring inclusive of downhole spot check of water quality was instructed as part of CE015 and this information is summarised in Table 13.

Table 13 Summary of Water Quality Measurements (Round 4 – 17.10.21)

Location	pH	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (%)	Redox (mV)
BH-BP-01	6.9	13.9	1388	6.3	-7
BH-OBC-01	Dry	Dry	Dry	Dry	Dry
BH-OBC-04	7.18	11.9	967	81.8	92.8
BH-OBC-04	Dry	Dry	Dry	Dry	Dry
BH-OBC-06	7.32	13.1	918	91.7	89.4
BH-OBC-07	7.16	12.4	871	28.6	96
BH-OBC-07	7.32	12.1	990	104.2	93.4
BH-OBC-11	7.37	12.4	851	25.4	98.7
BH-OBC-11	Dry	Dry	Dry	Dry	Dry
BH-OBC-12	7.12	13.8	865	32.2	92.2
BH-OBC-15	7.12	12.5	858	33	92.5
BH-PTR-02	6.59	12.4	1057	25	-0.2
BH-PTR-02	6.6	13.4	1028	17	11.8
BH-PTR-	6.76	12.8	895	8	-12.5
BH-PTR-04	8.34	12.8	1180	3.9	-65.8
BH-PTR-07	7.38	12.7	491	5.5	-11.3
BH-PTR-08	6.95	12	579	2.3	-105.6
BH-PTR-08	7.03	13	767	5.2	-38.4
BH-PTR-10	6.82	12.9	858	63.8	-45.5
BH-PTR-12	6.85	11.4	960	36.5	3.6
BH-PTR-13	6.79	11.9	884	90.3	141.6
BH-PTR-14	6.88	11.6	868	12.6	148.4
BH-PTR-15	Dry	Dry	Dry	Dry	Dry
BH-PTR-16	Dry	Dry	Dry	Dry	Dry
BH-PTR-18	Dry	Dry	Dry	Dry	Dry
BH-PTR-19	6.77	13.6	975	50.4	47.2
BH-PTR-21	6.75	13.7	760	33.1	-11.2
BH-PTR-27	6.82	12.4	981	11.7	-64.3
BH-PTR-30	7.29	12.6	670	6.3	60.1
BH-PTR-31	7.16	13.1	1065	12.1	70.7
BH-PTR-33	7.12	13.8	865	32.2	92.2

Location	pH	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (%)	Redox (mV)
BH-PTR-33	7.36	14.5	721	40.1	61.2
BH-PTR-35	7.49	14.4	661	10.5	46.6
BH-PTR-36	7.21	14.2	1409	12.2	62.5
BH-PTR-39	7.41	12.4	614	108.2	47.9
BH-PTR-41	7.22	11.7	688	12	96.4
BH-PTR-41	Dry	Dry	Dry	Dry	Dry
BH-PTR-42	7.11	11.7	680	58.6	92.6
BH-PTR-42	Dry	Dry	Dry	Dry	Dry
BH-PTR-43	7.02	11.6	787	9	56.2
BH-PTR-43	7	13	1682	6.1	-88.8
BH-PTR-45	7.27	12.2	1131	90.3	110.5
BH-TH-01	7.42	13.6	1161	79.6	79.3
BH-TH-03	Dry	Dry	Dry	Dry	Dry
BH-TH-05	Dry	Dry	Dry	Dry	Dry
BH-TH-06	Dry	Dry	Dry	Dry	Dry
BH-TH-08	Dry	Dry	Dry	Dry	Dry

S – Shallow Installation, **D** – Deep Installation

4.3.3 Ground Gas Monitoring

Land gases measured during three monitoring rounds undertaken to date are presented in Appendix I and summarised in Table 14.

Table 14 Summary of Ground Gas Monitoring

Location	Max. Methane (peak) (% vol)	Max. Carbon Dioxide (peak) (% vol)	Min. Oxygen (steady) (% vol)	Max. Carbon Monoxide (steady) (ppm)	Max. Hydrogen Sulfide (steady) (ppm)	Max. Borehole flow (peak) (l/h)
BH-BP-01	<0.1	0.7	18.6	1	<1	0
BH-OBC-01	0.1	2.3	16.7	<1	<1	0
BH-OBC-04 D	<0.1	0.2	13.7	<1	<1	0
BH-OBC-04 S	<0.1	0.9	13.4	<1	<1	0
BH-OBC-06	<0.1	1.2	17.2	<1	<1	0
BH-OBC-07 D	<0.1	1.2	17.6	5	<1	0
BH-OBC-07 S	<0.1	0.5	18.2	2	<1	0
BH-OBC-11 D	<0.1	1.1	18.1	2	<1	-10
BH-OBC-11 S	<0.1	3.7	15.2	<1	<1	0
BH-OBC-12	<0.1	0.3	18.7	<1	<1	0
BH-OBC-15	0.1	1.2	17.9	4	<1	-8.6

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BH-PTR-02 D	<0.1	2.1	13.7	1	<1	0
BH-PTR-02 S	<0.1	2.2	12.4	7	<1	17
BH-PTR-03A	<0.1	0.1	19.3	<1	<1	0
BH-PTR-04	<0.1	0.1	19.3	<1	<1	0
BH-PTR-07	0.1	0.1	19	<1	<1	0
BH-PTR08 D	<0.1	0.1	19.4	<1	<1	0
BH-PTR08 S	<0.1	0.1	19.4	<1	<1	0
BH-PTR-10	<0.1	0.1	19.5	<1	<1	0
BH-PTR-12	<0.1	0.1	19.4	<1	<1	-0.1
BH-PTR-13	<0.1	0.8	17.9	<1	<1	-0.1
BH-PTR-14	<0.1	1.2	19.1	1	<1	0
BH-PTR-15	<0.1	0.9	19	<1	<1	0
BH-PTR-16	<0.1	0.6	19	<1	<1	0
BH-PTR-18	<0.1	0.2	18.4	<1	<1	0
BH-PTR-19	<0.1	2.2	15.5	<1	<1	0
BH-PTR-21	<0.1	2	16.5	<1	<1	3.1
BH-PTR-27	<0.1	0.7	15.4	<1	<1	3.1
BH-PTR-30	<0.1	0.1	19.4	<1	<1	-0.1
BH-PTR-31	<0.1	1.2	16.3	<1	<1	-20.6
BH-PTR-33 D	<0.1	0.9	17.6	7	<1	1.4
BH-PTR-33 S	<0.1	1.3	12.5	<1	<1	0
BH-PTR-35	<0.1	2.5	14.5	<1	<1	3.1
BH-PTR-36	<0.1	0.3	18.6	<1	<1	-0.1
BH-PTR-39	<0.1	0.7	18.6	2	<1	-0.1
BH-PTR-41 D	0.1	1.6	17.4	2	<1	0.1
BH-PTR-41 S	0.1	4.3	12.4	<1	<1	0
BH-PTR-42 D	0.1	0.2	19.2	<1	<1	0
BH-PTR-42 S	<0.1	1.4	16.1	<1	<1	0
BH-PTR-43 D	<0.1	1.1	16.1	<1	<1	0
BH-PTR-43 S	0.1	1.7	14.4	<1	<1	0
BH-PTR-45	<0.1	2.2	16.6	1	<1	-0.1
BH-TH-01	0.1	0.9	18.5	<1	<1	0
BH-TH-03	<0.1	0.3	18.4	<1	<1	0
BH-TH-05	<0.1	0.5	18.4	<1	<1	0
BH-TH-06	<0.1	0.7	18.4	<1	<1	0
BH-TH-08	0.1	0.2	19.4	-0.1	<1	0