AG2983-19-AH86

APPLiED GEOLOGY

REPORT ON GROUND INVESTIGATION AT HAVERHILL BUSINESS PARK, SUFFOLK

REPORT STATUS SHEET

Client:	HE2 Haverhill 1 GP Limited
Report Title:	Report on Ground Investigation at Haverhill Business Park, Suffolk
Report Number:	AG2983-19-AH86
Report Status:	Validated Issue 1
Date:	June 2019

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APPENDICES

1.0 INTRODUCTION

1.1 Objectives and Scope of Investigation

An area of land off Iceni Way in Haverhill, Suffolk (the site) is being considered for redevelopment by HE2 Haverhill 1 GP Limited (the Client). The proposals for the site comprise the development of five industrial buildings, with associated access road, car parking, service yards and landscaping.

Applied Geology was appointed by the Client to undertake a Phase II ground investigation following cut and fill profiling of the site by others in 2016, in order to:

- Identify the depth of placed fill and geotechnical parameters of the fill material, to assist with the design of the supplementary ground improvement to be carried out by The Independent Stabilisation Company Ltd (ISC);
- Establish ground conditions and geotechnical parameters in the area of cut, to assist in the safe and economic engineering design;
- Determine the ground gas conditions;
- Establish the construction of the existing road Iceni Way and the composition of the underlying near surface soils;
- Provide an assessment of soils for off-site disposal;
- Provide an assessment of soils for risks to groundworkers.

The terms of reference/brief for the works were mutually developed between Nolan Associates (Engineer to the Client) and Applied Geology and are outlined in our proposal and estimate reference AG19-6745let001 dated 4th February 2019, which was based on an outline scope of works provided by Nolan Associates by email on the 23rd of January 2019.

The scope of works undertaken by Applied Geology comprised:

- A site inspection and walkover survey
- A review of reports provided by Nolan Associates:
    - 'Environmental and Earthworks Material Suitability Assessment Report' by Delta-Simons (ref. 15-0210.02 V2, dated September 2015);
    - 'Material Management Plan Verification Report' by Delta-Simons (ref. 15-0210.07, dated November 2016).
- Ground investigation together with sampling, monitoring and a programme of laboratory testing.
- Assessment and reporting of the results of the works.

Underground service plans for the site were provided by the Client on 13th March 2019. Post-earthworks topographic survey ('as built') drawings are included in the report by Delta-Simons.

1.2 Report Layout

This report presents a brief description of the site, a brief review of the Delta-Simons report and the factual results of the intrusive investigations carried out. An interpretation of the ground conditions and a discussion/assessment of the findings is presented in the later report text sections. The main text of the report has been produced in a concise format, including the use of data tables to summarise key information where possible. The report should be read in conjunction with the general procedures detailed in Appendix F and General Notes given at the end of the main text, which provide details of investigation techniques, assessment methodology and standards, health & safety and limitations and exceptions of the report. Drawings and factual data including exploratory hole records, in-situ results and laboratory testing results are presented in the other Appendices.

2.0 SITE DESCRIPTION AND PROPOSALS

2.1 Site Description

The site is located off Iceni Way, approximately 1.2km southeast of Haverhill town centre. The Ordnance Survey grid reference for the centre of the site is 567914, 244267 as shown on the Site Location Plan in Appendix A.

The site is elongate and irregular in plan shape, being c.220m by c.445m and covering an area of approximately 6.9 hectares. At the time of the fieldwork, there were two distinct areas of the site, with the larger northern area to the north of Iceni Way and a smaller southern area to the south of Iceni Way. The northern area was bound to the north by an area of open space, to the west by Bumpstead Road, the east by commercial properties and the south by Iceni Way. The southern area was bound to the north by Iceni Way, the west by a commercial property, the south by the A1017 and the east by another commercial property.

A site inspection/walkover was undertaken by Applied Geology on the 14th March 2019. Access to the site was gained off Iceni Way, with the entrance secured by an approximately 4m-wide metal gate. At the time of the inspection the site comprised vacant land that had been profiled into three approximately level plateaus. The northern site boundary was defined by a steep embankment slope that is understood to be formed from stabilised soils (see Section 3.0). The ground surface comprised clayey soil with rare vegetation throughout. Standing water was noted in several areas of the site. Trees were present along or adjacent to some site boundaries.

Standing water on the surface of the site

Northern edge of the site - lime stabilised retaining wall structure

2.2 Site Proposals

The proposals for the site comprise the development of five industrial buildings (warehouses with small areas of offices), with associated access road, car parking, service yards and landscaping, as shown on Drawing No. 6502-08, Rev A by AJA Architects dated January 2018.

This proposed plan indicates the presence of several drains along part of the northern site boundary, the western site boundary and the southern site boundary and also in the west of the site at Units 3 and 4. It is not known whether these drains remain following the earthworks in 2016.

3.0 INFORMATION FROM PREVIOUS REPORTS

The 'Environmental and Earthworks Material Suitability Assessment Report' and the 'Material Management Plan Verification Report' by Delta-Simons have been briefly reviewed and the pertinent findings are summarised below. It should be noted that these reports cover the site together with an area of land to the west. The parcels of land associated with the current site were referred to as NE1 and NE2 (north of Iceni Way) and SE2 (south of Iceni Way), as shown on the Historical Land Designations Plan (AG2983-19-03) in Appendix A.

<u>Delta-Simons Investigations (prior to the earthworks).</u>

- A Phase I Environmental Assessment was carried out and reported under reference 15-0210.01, dated March 2015;
- A factual Road Pavement Investigation was also completed and reported under reference 15-0210.04, dated August 2015;
- An Environmental and Earthworks Material Suitability Assessment was undertaken and reported under reference 15-0210.02 V2, dated September 2015;
- Anticipated ground conditions comprised Superficial Deposits of the Lowestoft Formation underlain by Solid Geology of the Lewes Nodular and Seaford Chalk Formations;
- Large stockpiles of site-won natural soils (clay with sand and gravel, Lowestoft Formation) were present on site prior to the earthworks;
- Ground conditions encountered during the fieldwork in SE2, south of Iceni Way, comprised localised Made Ground of sand and gravel with brick and concrete to depth of up to 0.6m below ground level (bgl), underlain by the Lowestoft Formation (stiff to very stiff clay with varying proportions of sand and gravel) to at least 5.45m bgl. Chalk was not proven. In NE1 and NE2, north of Iceni Way, Topsoil was encountered to depths of up to 2.2m bgl underlain by reworked Lowestoft Formation (firm to very stiff clay with varying proportions of sand and gravel) up to 10.2m bgl, the deepest being in the location of the stockpiles. In some stockpile locations, a layer of Topsoil was present at depth, recorded between 9.2m and 9.3m bgl in RA105 and between 10.2m and 10.35m bgl in RA108, suggesting original ground level. The Lowestoft Formation was proven to a depth of up to 10.35m bgl, underlain by weathered Chalk (cream slightly gravelly sandy silt, Grade Dm) to at least 11.45m bgl;
- Groundwater was standing at depths of between 2.97m and 8.38m bgl, suggesting perched pockets of water within the Superficial Deposits;

- Soil and groundwater testing did not identify any concentrations of contaminants above the relevant screening values;
- Two gas monitoring visits identified elevated concentrations of methane (up to 15.9%vol) and carbon dioxide (up to 11.2%vol), resulting in the site being classified as Characteristic Situation 2. These elevated concentrations were attributed to decomposition of organic matter within the Topsoil;
- Buried concrete testing classified the soils on site as DS-2, AC-1s;
- Atterberg limit tests on the Lowestoft Formation identified the clay to be of low to medium shrinkage potential;
- The stockpiles of soil on site and the in-situ Lowestoft Formation were predominantly classified as Class 2A/2B and were deemed suitable in their current condition for use as earthworks fill. However, to achieve a more uniform material and one less prone to deterioration from inclement weather, Delta-Simons stated that soil stabilisation may be considered;
- Where the in-situ Lowestoft Formation was present near surface, an allowable bearing capacity of around 100kN/m^2 was recommended for traditional spread foundations.

Earthworks Strategy Report.

- An Earthworks Strategy was developed by Baynham Meikle Partnership Ltd. and was reported under reference NSB / 12070 / ERW Issue 2 and dated 7th October 2015.
- The strategy outlined that fill should be placed in accordance with the Specification or Highway Works and a Materials Management Plan (MMP).
- The strategy proposed that 'geotechnical tests such as CBR plate load test' were carried out during earthworks 'to confirm the level of compaction achieved'. No specific geotechnical tests, except CBR, were specified and no end product performance criteria were set.

Earthworks.

- Earthworks were carried out in 2016 by Carey Group PLC on the site and on land to the west, and achieved a cut-fill balance. In general, in-situ soil from SE2 south of Iceni Way and stockpiles of soil from NE2 (the eastern half of land north of Iceni Way) were placed in NE1 (the western half of land north of Iceni Way) to raise levels. In addition, around 1m of in-situ soil from the east of NE2 was placed in NE1;
- Delta-Simons visited site every two weeks during the earthworks to record the activities carried out and deal with any issues arising;
- Soils were tested prior to the earthworks to confirm their suitability, both environmentally and geotechnically;
- Plate bearing tests to determine equivalent CBR were carried out on the fill by ESG and recorded values of between 0.8-6.9% in NE1, values of between 3.7-7.2% in NE2 and between 1.1-3.4%in SE2. Values for cement stabilised soil in NE1/NE2 were between 1.0-23.5%;
- A cement stabilised earth retaining structure / steep embankment slope (residing at c. 70 degrees) was constructed along the northern site boundary to retain the earthworks and designed by ISC;
- No hotspots of contamination were identified during the earthworks.

4.0 GROUND INVESTIGATION WORKS

4.1 Fieldwork

The following scope of fieldwork was undertaken by Applied Geology Ltd. between the 21st and 27th March 2019:

- 13No Driven Continuous Sampling Boreholes (ref. DCS201 to DCS213) to depths of between 3.0m and 5.45m bgl;
- 10No Machine Excavated Trial Pits (ref. TP201 to TP210) to depths of between 3.0m and 4.7m bgl;
- 31No Static Cone Penetration Tests (ref. CPT201 to CPT230 & CPT202A) to depths of between 5.0m and 15.0m bgl;
- 3No Road Cores undertaken in Iceni Way (ref. C1 to C3) to depths of between 0.64m and 0.92m bgl.

The borehole and trial pit records are included in Appendix B and the CPT factual report forms Appendix C, with the gas monitoring results included in Appendix D. The SPT calibration certificate for the driven continuous sampling boreholes is also included in Appendix B.

The locations of the exploratory holes were based upon a proposed layout specified by Nolan Associates with locations modified by Applied Geology to account for access and buried services. The locations were cleared of buried services and set out on site by Midland Survey Ltd. CPT locations were restricted to the area of land north of Iceni Way, where engineered fill material (Made Ground) has been placed. The sampling strategy for the exploratory hole locations was to provide best overall coverage.

The positions of the exploratory holes and co-ordinates were surveyed by Midland Survey Ltd and are included on the exploratory hole records and CPT records in Appendix B and Appendix C respectively. The locations are presented on Drawing No. AG2983-19-02 in Appendix A.

4.2 Instrumentation and Monitoring

On completion of boring, 50mm diameter standpipes were installed in selected driven sampling boreholes as follows, with further details included on the relevant borehole logs in Appendix B

Borehole	Response zone depth (m)	Strata
DCS202	1.0 – 1.5	Lowestoft Formation
DCS203	1.0 – 3.0	Lowestoft Formation
DCS204	1.0 – 5.0	Lowestoft Formation
DCS205	1.0 – 3.0	Made Ground & Lowestoft Formation
DCS206	1.0 – 4.0	Made Ground (Engineered Fill)
DCS207	1.0 – 3.0	Made Ground (Engineered Fill)
DCS208	1.0 – 4.0	Made Ground (Engineered Fill)

Borehole	Response zone depth (m)	Strata
DCS209	1.0 – 1.3	Made Ground (Engineered Fill)
DCS210	1.0 – 3.0	Lowestoft Formation
DCS211	1.0 – 3.0	Lowestoft Formation
DCS212	1.0 – 3.0	Lowestoft Formation

Washed silica gravel (2-6mm) was used as the filter medium with a bentonite seal between the response zone and ground surface. Each standpipe was fitted with a push-in bung and single gas tap and was finished with flush metal cover concreted in place.

Ground gas and groundwater monitoring visits were undertaken on four occasions from the 2nd April to the 25th April 2019 including during two periods of low and/or falling atmospheric pressure. Each monitoring well was monitored for concentrations of carbon dioxide, methane, oxygen, volatile organic compounds (VOCs), flow rates and differential pressures and water level. The monitoring results are included in Appendix D.

4.3 Laboratory Testing

Geotechnical laboratory testing was undertaken on selected samples and comprised the following:

- 12No natural moisture content tests;
- 12No Atterberg limit tests;
- 8No BRE SD1 Greenfield tests;
- 6No BRE SD1 Greenfield & pyrite suite tests.

Chemical testing was undertaken based upon the historical data for the site and site observations during the fieldwork. Testing was undertaken to provide an indication of risk of contamination to groundworkers and an assessment of soils, should off-site disposal be required. Nine samples of Made Ground (Engineered Fill) were analysed for the following suite of contaminants:

- Selected metals suite [arsenic, boron, beryllium, cadmium, chromium (total, trivalent and hexavalent), copper, mercury, nickel, lead, zinc, selenium, vanadium];
- Speciated Polycyclic Aromatic Hydrocarbons (PAH);
- Total Petroleum Hydrocarbons (TPH, 3 band);
- Asbestos;
- Total Organic Carbon (TOC).

In addition, four samples of the Lowestoft Formation were submitted for inert Waste Acceptance Criteria (WAC) testing.

Laboratory test results are included in Appendix E.

5.0 GROUND CONDITIONS

5.1 Strata Encountered

The ground conditions at the site reflect that the site has previously been the subject of a cut and fill exercise. The exploratory hole records from this investigation, recorded depth to natural strata from the Delta-Simons' pre-earthworks investigation and current site levels suggest cut in the southeast and south and fill in the north and northwest.

Generally, Made Ground (Engineered Fill) was encountered in areas of fill and a thin layer of reworked Lowestoft Formation in areas of cut, underlain by the Lowestoft Formation. Groundwater was not encountered during drilling or excavation. Full details of the strata encountered are given on the exploratory hole records presented in Appendix B. A generalised ground profile is presented below to summarise the information. An SPT N value versus depth plot is included in Appendix A.

Stratum	Depth to Top of Strata (m bgl)	Thickness (range) (m)	Comments
Made Ground (Including Engineered Fill)	GL	0.3 - >4.45	Present in the north and northwest. Thickens to the northwest.
Reworked Lowestoft Formation	GL	0.05 – 0.4	Present in the south and southeast, where no Made Ground.
Lowestoft Formation	GL-2.4	>5.4m	Proven across the site, except where Made Ground was thickest.

5.2 Made Ground (Including Engineered Fill)

Made Ground was encountered in ten out of twenty-three boreholes and trial pits (DCS205-209, TP203, TP205 & TP207-209) in the north and northwest of the site, from ground level to depths of between 0.3m and >4.45m bgl.
The depth to the base of the Made Ground north of Iceni Way, inferred from changes in the cone resistance, sleeve friction resistance and undrained shear strength values from the cone penetration tests, ranged between 0.5m and 8.0m bgl. Made Ground is considered to be absent in CPT209 in the southwest of Unit 4.

With the exception of TP203 on Unit 5, the Made Ground is considered to be site-won Lowestoft Formation strata cut from elsewhere on site and placed in 2016. The Made Ground typically comprised brown gravelly clay, with the gravel comprising chalk, flint and rare quartzite. Occasional rootlets were encountered, together with rare pockets of plant material in TP207 between 3.5m and 4.0m bgl and relict Topsoil in DCS205 between 1.4m and 1.6m bgl. Man-made detritus was noted in TP205 from ground level to 0.3m bgl and comprised concrete fragments and rare glass and plastic fragments.

The Made Ground in TP203, from ground level to 0.3m bgl, comprised reworked Lowestoft Formation (present elsewhere on Unit 5) with rare fragments of brick and may be associated with the construction of Iceni Way adjacent to the north.

SPT N values in the Made Ground ranged between N=8 and N=21. Applying the empirical relationship between SPT N value and undrained shear strength and using an F1 factor of 4.8 (mean PI of 28%) indicates approximate equivalent shear strengths of between 40 and 100kN/m^2 (medium to high strength). Hand shear vanes carried out in the trial pits recorded shear strengths of between 139kN/m^2 and 223kN/m^2 (high to very high strength). Consistency and liquidity indices, based on the Atterberg limit testing, indicate the Made Ground to range between soft and very stiff. The variation in the strength of the Made Ground determined from this ground investigation accords with the variation in CBR recorded on the fill materials during earthworks (Section 3.0 refers) and the understanding that the material used to raise levels on site was not subject to a strict end product criteria earthworks specification.

Seven Atterberg limit tests on the Made Ground recorded plasticity index values of between 26 and 32, indicating the clay to be of medium shrinkage potential. Liquid limits ranged between 46% and 53%, plasticity limits between 19% and 22% and moisture contents between 17% and 24%.

Assessment and interpretation of the CPT data has been carried out to determine the approximate thickness of Made Ground at each test location. In this interpretation general criteria were developed based upon engineering experience and the trends apparent in the ground conditions and data. The criteria used to determine the upper horizons of the natural Lowestoft Formation were generally cone resistance of >4-5 MPa and / or sleeve friction of >100kPa and / or equivalent undrained shear strength of >100-150kPa. These criteria were tempered by engineering judgment and the ground model developed using the historic and current ground investigation data. Based on this assessment the following Made Ground depths have been interpreted and a contour plot of Made Ground depth has been developed using Surfer 11 software and presented as Drawing AG2983-19-04 in Appendix A. Actual depths may vary.

CPT Test Location	Interpreted Depth of Made Ground (m bgl)	Reduced Level to Base of Made Ground (m OD)
CPT201	4.5	79.669
CPT202	5.5	79.619
CPT203	7.5	79.659
CPT204	7.5	79.604
CPT205	0.5	79.865
CPT206	4.0	79.614
CPT207	6.0	79.630
CPT208	8.0	79.625
CPT209	0.0	79.856
CPT210	2.0	79.647
CPT211	6.5	79.646
CPT212	0.5	79.668
CPT213	1.5	79.643
CPT214	0.5	79.651
CPT215	3.5	79.640
CPT216	4.5	81.877
CPT217	3.0	81.857
CPT218	4.0	81.904
CPT219	1.5	81.867
CPT220	2.0	81.885
CPT221	3.0	81.929
CPT222	2.5	81.849
CPT223	2.5	81.880
CPT224	5.0	81.875

CPT Test Location	Interpreted Depth of Made Ground (m bgl)	Reduced Level to Base of Made Ground (m OD)
CPT225	2.0	81.912
CPT226	3.0	81.893
CPT227	6.0	81.879
CPT228	1.5	81.878
CPT229	3.2	81.906
CPT230	4.0	81.862

5.3 Reworked Lowestoft Formation

This stratum was present in areas of cut from the earthworks in 2016 and is differentiated from the underlying Lowestoft Formation due to it being of lower strength and brown, rather than bluish mottled orangish brown.

The reworked Lowestoft Formation was encountered in twelve out of twenty-three boreholes and trial pits (DCS201, DCS203, DCS204, DCS210-DCS213, TP201, TP202, TP204, TP206 & TP210) in the south and southeast of the site, from ground level to depths of between 0.05m and 0.4m bgl.

The reworked Lowestoft Formation generally comprised very soft to soft brown gravelly clay with gravel of flint and chalk and represents overlying wet and strain softened natural deposits.

5.4 Lowestoft Formation

The Lowestoft Formation was encountered in seventeen out of twenty-three boreholes and trial pits (all except DCS206-DCS208 & TP207-TP209) from between ground level and 2.4m bgl to at least 5.45m bgl.

This stratum generally comprised bluish grey occasionally mottled orangish brown gravelly clay with gravel of flint and chalk.

SPT N values in the Lowestoft Formation ranged from N=11 to N=31 between 1.2m and 1.65m bgl, from N=15 to N=42 between 2.0m and 2.45m bgl and from N=18 to N=64 between 3.0m and 3.45m bgl. Where the stratum could be penetrated below this, SPT N values ranged between N=26 and N=39. Hand shear vanes carried out in the trial pits recorded shear strengths of between 107kN/m^2 and 226kN/m^2, suggesting the Lowestoft Formation to be stiff to very stiff. Consistency and liquidity indices, based on the Atterberg limit testing, also indicate the Lowestoft Formation to be stiff to very stiff.

Five Atterberg limit tests on the Lowestoft Formation recorded plasticity index values of between 25 and 28, indicating the clay to be of medium shrinkage potential. Liquid limits ranged between 44% and 48%, plasticity limits between 19% and 21% and moisture contents between 16% and 20%.

5.5 Road Cores

The three road cores along Iceni Way encountered a thickness of asphalt of between 0.27m and 0.29m, underlain by silty sandy gravel of quartzite, sandstone and siltstone to depths of between 0.64m and 0.92m bgl. Clay of the Lowestoft Formation was present beneath. A site visit report detailing the thickness of each asphalt layer and including photographs of the road cores is presented in Appendix B.

5.6 Groundwater

All of the exploratory holes were dry during excavation and drilling. The boreholes remained dry during the subsequent monitoring visits, with the exception of DCS202, which recorded groundwater during the second, third and fourth monitoring visits between 0.43m bgl and 0.65m bgl. This is considered to represent a localised pocket of perched water rather than 'true' groundwater.

5.7 Contamination

There was no visual or olfactory evidence of any gross contamination observed in the boreholes or trial pits or soil examined beneath the road cores.

5.8 Ground Gas

Four phases of ground gas monitoring have been undertaken as part of this investigation, the results of which are included in Appendix D. The results have been separated into land to the north and south of Iceni Way, given that land to the south was cut and land to the north was both cut and filled.

South of Iceni Way

Methane concentrations of <0.1%vol were recorded, together with very low carbon dioxide concentrations of between 0.1%vol and 1.8%vol. Near atmospheric oxygen concentrations were recorded. Flow readings were taken over a three-minute period and a maximum average flow rate of <0.1l/hour was recorded. Very low concentrations of VOC of between <0.1ppm and 4.4ppm were also recorded.

Based on the worst-case average gas flow and the highest average methane and carbon dioxide readings, a gas screening value has been calculated in accordance with CIRIA C665 for methane of 0.0001l/hr and for carbon dioxide of 0.0018l/hr.

North of Iceni Way

In general, methane concentrations of between <0.1%vol and 5.4%vol were recorded, together with carbon dioxide concentrations of between 0.1%vol and 0.3%vol whilst oxygen concentrations were recorded at near atmospheric to marginally depleted (21.1%vol-16.1%vol). However, much higher concentrations were recorded in DCS205 and DCS206 with methane being recorded between 5.2%vol and 19.5%vol in DCS205 and 0.1%vol and 16.1%vol in DCS206. Carbon dioxide was also elevated in these two holes recorded at between 5.9%vol and 8.1%vol in DCS206 and 0.1%vol and 16.1%vol in DCS205. Oxygen concentrations in DCS205 and DCS206 were often depleted at between 0.3%vol and 16.1%vol with near atmospheric levels recorded in DCS206 on the second (21%vol) and third (19.3%) visits only.

Flow readings were taken over a three-minute period and a maximum average flow rate of <0.1l/hour was recorded. Very low concentrations of VOC of between <0.1ppm and 6.6ppm were also recorded.

The highest concentrations of methane and carbon dioxide were recorded during periods of low atmospheric pressure on the first and fourth visits in DCS205 and DCS206. The ground conditions at DCS205 (beneath Unit 1) recorded 2.4m of Made

Ground, which included a layer of relict Topsoil between 1.4m and 1.6m bgl. In DCS206 (beneath Unit 4) Made Ground was recorded in excess of 4.45m bgl.

Based on the worst-case average gas flow and the highest average methane and carbon dioxide readings, a gas screening value has been calculated in accordance with CIRIA C665 for methane of 0.0195l/hr and for carbon dioxide of 0.0129l/hr.

6.0 GEOENVIRONMENTAL ASSESSMENT

6.1 Human Health Risk Assessment

Whilst an assessment of risk to the proposed end users is not part of the scope of this investigation, an indication of potential risks of contamination to the groundworkers has been requested.

Contamination testing of the Made Ground (Engineered Fill) on site (north of Iceni Way) do not indicate the presence of contaminants at concentrations that require special precautions. Concentrations of PAHs and TPH were generally below the relevant laboratory limits of detection, except for low concentrations of PAHs in DCS205 at 0.3m bgl and very low concentrations of TPH in TP207 at 0.8m bgl and TP209 at 0.5m bgl. No asbestos was identified. Standard PPE and welfare facilities should be provided.

6.2 Disposal of Soil Arisings

General comments regarding the procedures for the assessment of waste soil for off-site disposal purposes is included in Appendix F.

The general contamination testing of the fill material suggests that the soils would not be classified as hazardous waste.

The four WAC tests on the in-situ Lowestoft Formation north and south of Iceni Way demonstrate compliance with the WAC limits for inert landfills, except for two marginal exceedances of fluoride of 11mg/kg (in DCS201) and 13mg/kg (in TP210), above the compliance value of 10mg/kg. The compliance value for stable non-reactive hazardous waste in non-hazardous landfill is 150mg/kg, well above the concentrations recorded. We recommend should soils need to be disposed off-site, all of the contamination test results should be forwarded to the soil recycling facility or landfill site to confirm their acceptance. Should the landfill not accept the soils as inert waste, they are likely to be accepted as non-hazardous waste, for which WAC testing is not required.

7.0 GEOTECHNICAL ASSESSMENT

7.1 General

The proposals for the site comprise the development of five industrial buildings (warehouses with small areas of offices), with associated access road, car parking, service yards and landscaping, as shown on Drawing No. 6502-08, Rev A by AJA Architects dated January 2018.

As part of the earthworks carried out by Carey Group PLC in 2016, the site was cut south of Iceni Way and both cut and filled north of Iceni Way. Therefore, the

foundation and floor slab assessment has been separated into three distinct areas comprising cut, deep fill and areas straddling both cut and fill. A contour plan showing the conjectured thickness of the Made Ground (AG2983-19-04) has been developed using Surfer 11 contouring software and was based on interpretation of the CPT data together with the trial pit and borehole data and is reproduced in Appendix A.

7.2 Foundations and Floor Slabs

7.2.1 Areas Straddling Cut and Fill North of Iceni Way (Unit 1, 2 and 4)

The areas of the proposed Units 1, 2 and 4 straddle areas of both cut in the south / southeast and increasingly deep fill in the centre and north of the footprints.

The ground conditions encountered at Unit 1 comprised reworked Lowestoft Formation in the eastern and southern extents of the building to depths of 0.05m and 0.3m bgl and Made Ground increasing in thickness up to a maximum of around 3.2m bgl along the northern margins of the footprint. The Made Ground was underlain by the Lowestoft Formation.

Ground conditions encountered at Unit 2 comprised reworked Lowestoft Formation in the southern extent of the building to a depth of 0.05m and Lowestoft Formation at ground level in the southeastern extent of the building. Made Ground up to a maximum thickness of around 3.0m bgl was present beneath the remainder of the building, underlain by the Lowestoft Formation.

Ground conditions encountered at Unit 4 comprised a limited thickness of Made Ground beneath the southern margin of the footprint increasing to up to around 1.5m to 2.0m bgl in the north of the footprint, which was again underlain by the Lowestoft Formation.

In summary, the ground conditions beneath these three plots appears to comprise a 'wedge' of fill that thickens to the north being up to between c. 2m and 3m thick along the northernmost margins of the proposed footprints. For the majority of the footprints of these units deepened pad foundations would be suitable, however, extending the pads up to and potentially over 3m bgl in the northern margins is likely to prove impractical. Notwithstanding the difficulties of constructing pads at c. 3m depth, the variation in thickness of fill across the footprint raises potential settlement concerns for a ground bearing floor slab where total and differential settlements would be unpredictable and potentially unacceptable. As a result it is considered that alternate foundation solutions will be required. The following may be considered:

Vibro replacement ground treatment.

The Made Ground (Engineered Fill) may be suitable for treatment by vibro replacement ground improvement processes. Treatment (if the soils are suitable) would be expected to extend through the full depth of any Made Ground beneath the proposed foundations and also beneath floor slabs if a ground bearing design is adopted. Normally, shallow reinforced spread foundations and floor slabs would be appropriate.

The advice of a specialist contractor should be sought to confirm suitability for treatment. Specifically, confirmation should be sought that the Made Ground

is suitable for treatment in respect of the time since placement and potential for ongoing self-weight settlement.

Controlled Modulus Columns / Stabilised Soils.

The Made Ground may be suitable for treatment by a combination of re-engineering using cement or lime stabilisation in association with Controlled Modulus Columns in areas of deeper Made Ground. The advice of specialist contractors should be sought and the information from this investigation (in particular the CPT results) should be provided to them to enable their designs. Specialists may wish to carry out some site specific suitability testing.

Piled foundations.

As an alternative the line and column loads from the proposed units could be supported upon a scheme of piles carrying their working load in a combination of skin friction and end bearing in the stiff clay of the natural Lowestoft Formation. The advice of specialist contractors should be sought in respect of the most suitable method and design. The effects of potential negative skin friction in the Made Ground should be considered in any piled foundation design. It may also be feasible to fully suspend the floor slabs off the piles by utilising existing pile caps where possible combined with additional piles where necessary.

7.2.2 Area of Deep Fill North of Iceni Way (Unit 3)

Ground conditions encountered at Unit 3 comprised Made Ground (Engineered Fill) up to around 8.0m bgl, underlain by the Lowestoft Formation. Made Ground thickness over the majority of the footprint is interpreted to be greater than 3m bgl and hence, traditional pad foundations are not feasible and an alternative foundation solution such as ground improvement or piles would be necessary.

It is understood from information provided by Nolan Associates that the currently preferred solution comprises a ground improvement scheme combining Controlled Modulus Columns with re-engineered and cement and / or lime stabilised soil carried out by a specialist stabilisation contractor. We understand it is proposed that a thickness of 3m of fill will be excavated, re-engineered and stabilised across the whole footprint in order to support a reinforced raft. The information from this investigation and in particular the CPT results should be provided to the specialist contractor to enable their designs.

7.2.3 Areas south of Iceni Way in Cut (Unit 5)

Ground conditions encountered beneath Unit 5 comprised reworked Lowestoft Formation or Made Ground (reworked Lowestoft Formation with rare brick fragments) from ground level to depths of between 0.25m and 0.4m bgl. Beneath was the Lowestoft Formation, encountered to the base of the exploratory holes.

It is considered that the in-situ Lowestoft Formation beneath Unit 5 is suitable to support conventional spread foundations. These should be placed below any Made Ground or reworked Lowestoft Formation and also beneath any soft or loose natural materials in the upper weathered horizons of the Lowestoft Formation. It will be

necessary to embed the foundations within the in-situ firm to stiff Lowestoft Formation beneath these materials.

The ground conditions comprise medium shrinkage potential soils. Outside the zones of influence of trees, conventional shallow spread foundations may be adopted at a minimum depth of 0.9m bgl to place such foundations below the zone of seasonal shrinkage/heave. Within the zones of influence of trees or hedges, minimum foundations depths should initially be based on the depths given within the NHBC standards.

Strip/trench fill (up to 1m wide) and pad foundations (up to 2m x 2m) competently designed to the above requirements may adopt an allowable bearing pressure of up to 150kN/m^2. This is based on a minimum shear strength of 75kN/m^2 in the firm to stiff deposits using traditional methods of bearing capacity calculations e.g. as set out in Tomlinson 7th Edition and a factor of safety of 3 against bearing capacity failure and whilst limiting total settlement to less than 25mm.

If conditions, significantly at variance to those described herein are encountered, specialist geotechnical advice should be sought to make appropriate assessment and recommendations.

Given that the Made Ground and reworked Lowestoft Formation do not exceed 600mm in thickness, a ground bearing floor slab is considered suitable for the proposed industrial building. Provided firm to stiff natural Lowestoft Formation soils are exposed at formation then an equilibrium CBR value of 5% (modulus of subgrade reaction of c.35MN/m^3) can be assumed for design. On such soils a uniformly distributed load of up to 50kN/m^2 is considered appropriate, higher loads or non-uniformly distributed loads may require further assessment. The formation should be proof rolled and any soft spots removed and replaced with suitable granular fill.

7.3 Ground Gas

The ground investigation and historic records indicate that the land to the south of Iceni Way, previously referred to as SE2 and in the area of the proposed Unit 5, was cut whilst the rest of the site located to the north of Iceni Way was both cut and filled. Hence, with respect to ground gas these two areas have been assessed separately as follows.

7.3.1 South of Iceni Way

Based on the historical data, the ground conditions encountered and the calculated gas screening values (GSVs), Unit 5 south of Iceni Way can be characterised as Situation 1, for which no special gas protection measures are required.

The VOC monitoring results were of very low order and therefore, the installation of hydrocarbon-resistant membranes if not considered warranted.

This assessment should be agreed with the Local Authority prior to commencing construction.

7.3.2 North of Iceni Way

Based on the historical data, ground conditions encountered, calculated gas screening values (GSVs) and the highest concentrations of methane and carbon dioxide, Units 1, 2, 3 & 4 north of Iceni Way should be characterised as Situation 2, for which low level gas protection measures are required. This should include a gas membrane, with all joints and penetrations sealed, and possibly underfloor venting.

The calculated GSVs and general concentrations recorded would classify the site as Characteristic Situation 1 (CS1), however, concentrations of carbon dioxide and methane, primarily in DCS205 and DCS206, were relatively consistently above the 'typical concentrations' for CS1 of 5% carbon dioxide and 1% methane. These higher concentrations coincide with organic soils being recorded and also the area of greatest Made Ground (Engineered Fill). Hence, it is considered likely that the elevated methane and carbon dioxide concentrations recorded are being generated by decomposition of putrescible organic material in the buried / relict Topsoil within the Made Ground. This is further supported by the lack of flow and absence of any credible off-site sources of ground gas. Given the concentrations recorded and the presence of deep Made Ground, containing some buried and / or relict Topsoil layers, it is recommended that the site areas to the north of Iceni Way be classified as CS2 in line with the advice within CIRIA C665. Some precautionary gas protection measures are required for CS2 and based upon the guidance in BS8485 and assuming Building Type D (large commercial / industrial) a gas protection score of 1.5 is required. This score can be achieved in a variety of ways and reference should be made to BS8485 for full details, however, the proposed reinforced raft for Unit 3 is likely to fulfil the 1.5 points required whilst the 3m of stabilised soil would also provide an additional low permeability layer beneath the unit. For Units 1, 2 and 4 ground bearing floor slabs (if well reinforced) could achieve 0.5 points and the remaining point could be achieved using a passive sub floor dispersal layer or a gas resistant membrane fully validated in accordance with CIRIA C735.

The VOC monitoring results were of very low order and therefore, the installation of hydrocarbon-resistant membranes if not considered warranted.

Gas protection measures should be installed as described in BRE414 and agreed with the Local Authority prior to commencing construction.

7.4 Excavations

Excavations of potentially up to 2.5m to 3m deep may be undertaken if deep pad foundations are adopted for Units 1, 2 and 4 and for the excavation and re-engineering of soils beneath Unit 3. At these depths, excavations are expected to be in a combination of Made Ground and clay of the Lowestoft Formation. These materials may be prone to some short-term instability and spalling and may need to be graded back to a stable angle or trench support should be provided. Trench support or the angle of batter should be designed by an appropriately qualified engineer or competent person to suit the required depth and the ground and groundwater conditions. Significant groundwater ingress is not expected, although it is recommended that some provision for obtaining sump pumping equipment is made to control any minor seepage and run off in wet weather conditions.

7.5 Pavement Design

The current Iceni Way appears to have a road construction of between 0.27m and 0.29m of asphalt underlain by subbase to depths of between 0.64m and 0.92m bgl. Beneath, clay of the Lowestoft Formation was encountered.

For new roads, service yards and car parking where the formation soils comprise in situ natural firm to stiff Lowestoft Formation an equilibrium CBR value of 5% is recommended. This is based on the classification testing, soil type, construction conditions and reference to IAN 73/06. Near surface very soft or soft deposits should be stripped off and the surface proof rolled.

The provenance of the fill materials on site is not fully known and neither is the method of filling, hence, due to this and combined with the inherent variability of the Made Ground, an equilibrium CBR value of 2% is recommended for this stratum. This may be improved with proof rolling and / or by stabilisation with lime and / or cement followed by adoption of a design CBR value in line with the recommendations of a specialist contractor.

The Lowestoft Formation is likely to be non-frost susceptible based on the plasticity index values.

7.6 Buried Concrete and Services

As defined by BRE Special Digest 1, Concrete Aggressive Ground, 2005 the Design Sulphate Class and the Aggressive Chemical Environment for Concrete (ACEC) has been assessed for each of the strata encountered. Following the results of the geotechnical testing, the characteristic values for each stratum have been determined and are detailed in the table below.

Strata	Soluble Sulphate (mg/l)*1	Total Potential Sulphate (%)*1	pH	Design Sulphate Class*2	ACEC*3
Made Ground	1500	0.6	7.5	DS-2	AC-1s
Lowestoft Formation	2000	2.2	7.5	DS-4	AC-3s

Notes:
*1: Characteristic values are rounded to the nearest 100mg/l or 0.1%.
*2: Based on soluble sulphate.
*3: Assumes static groundwater for all strata.

The results of the sulphate tests carried out have identified the Design Sulphate Class for the Made Ground to be DS-2, with the Aggressive Chemical Environment for Concrete (ACEC) being AC-1s as defined by the BRE Special Digest 1, Concrete Aggressive Ground, 2005 for a greenfield site and static groundwater regime. The Design Sulphate Class for the Lowestoft Formation has been calculated to be DS-4, with the Aggressive Chemical Environment for Concrete (ACEC) being AC-3s. Further reference should be made to BRE Special Digest 1 for requirements in respect of types of cement and aggregate to be used and variations in type of concrete construction.

No evidence of hydrocarbons was noted during the ground investigation and TPH fractions from the laboratory testing undertaken were very low or below the laboratory detection limits. It should be noted that the full suite of testing required by the UKWIR guidance has not been undertaken as part of this investigation and such testing may be required by the Water Authority once routes of proposed water supply pipes are known. Further guidance on this subject is included within Appendix F.

7.7 Conclusions and Recommendations

Traditional shallow pad foundations are considered appropriate for Unit 5 to the south of Iceni way, bearing within the firm to stiff clay of the Lowestoft Formation with an allowable bearing pressure of 150kN/m^2 whilst limiting total settlement to <25mm. The ground gas regime for Unit 5 has been determined as CS1 for which no gas protection measures are required.

The thickness of Made Ground (Engineered Fill) material beneath the proposed plots north of Iceni Way likely precludes the use of traditional pad foundations bearing on to natural soils, hence, alternate foundation solutions such as ground improvement or piles will be required. It is understood Controlled Modulus Columns and stabilised soils are being considered beneath Unit 3 whilst vibro replacement ground treatment is being considered for the remaining units. Elevated methane and carbon dioxide concentrations were recorded beneath the plots north of Iceni Way for which Characteristic Situation 2 is considered appropriate. Some precautionary gas protection measures are required for CS2 and reference should be made to BS8485.

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GENERAL NOTES

A) The assessment made in this report is based on the site terrain and ground conditions revealed by the various field investigations undertaken and also any other relevant data for the site including previous site investigation reports (if available) and desk study data. There may be special conditions appertaining to the site, however, which have not been revealed by the investigation and which have not, therefore, been taken into account in the report. The assessment may be subject to amendment in the light of additional information becoming available. It must be recognised that many of the Environmental Searches obtained during the course of the desk study are often lengthy. Applied Geology have, where appropriate and in the interests of simplicity, only reproduced the summary of the searches within the report. A full copy of all the search data is held at the Applied Geology office and is available for inspection if required.

B) The services provided are defined within our proposal and are carried out in line with the terms of appointment between Applied Geology and the Client.

C) Where any data supplied by the Client or other external source, including that from previous site investigations, has been used it has been assumed that the information is correct. No responsibility can be accepted by Applied Geology for inaccuracies within this data.

D) Whilst the report may express an opinion on possible configurations of strata between or beyond the exploratory locations, or on the possible presence of features based on either visual, verbal or published evidence this is for guidance only and no liability can be accepted for the accuracy.

E) Comments on groundwater (and landfill gas) conditions are based on observations made during the course of the present and past investigations or with reference to published data unless otherwise stated. It should be noted, however, that groundwater (and landfill gas) levels vary due to seasonal (or atmospheric conditions) or other effects.

F) The copyright of this report and other plans (and documents prepared by Applied Geology) is owned by Applied Geology and no such report, plan or document may be reproduced, published or adapted without the written consent of Applied Geology. Complete copies of the report may, however, be made and distributed by the Client as an expedient in dealing with matters related to its submission.

G) This report is prepared and written in the context of the proposals stated in the introduction to the report and should not be used in a differing context. Furthermore, new information, improved practices and legislation may necessitate an alteration to the report in whole or in part after its submission. Therefore with any change in circumstances or after the expiry of one year from the date of the report, the report should be referred to Applied Geology for re-assessment and if necessary, re-appraisal.

H) The survey was conducted and this report was prepared for the sole internal use and reliance of the Client. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Applied Geology. If an unauthorised third party comes into possession of this report they rely on it at their peril and Applied Geology owes them no duty of care and skill.

I) Ground conditions should be monitored during the construction of the works and the recommendations of the report re-evaluated in the light of this data by the supervising geotechnical or geo-environmental engineers.

J) Unless specifically stated, the investigation has not taken into account the possible effects of mineral extraction.

K) The works performed are not a comprehensive site characterisation and should not be construed as being such.

L) The findings of the geo-environmental risk assessment are based on information obtained from a variety of sources which Applied Geology believe to be correct. Applied Geology cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

M) The report represents the findings and opinions of experienced geo-environmental consultants. Applied Geology does not provide legal advice and the advice of lawyers may be required.

N) Conditions at the site are subject to change from the time of the site inspection.

O) It is possible that researches carried out by Applied Geology, whilst fully appropriate for a phase 1 desk study, failed to indicate the existence of important information sources. Assuming such indicators actually exist, their information could not have been considered in the formulation of Applied Geology findings and opinions.

P) The economic viability of the proposals referred to in the report, or of the solutions put forward to any problems encountered, depends on very many factors in addition to geotechnical considerations and hence its evaluation is outside the scope of this report.

Q) Applied Geology operates as a Consultancy and does not operate it's own laboratory for soil testing, this work being sub contracted to known and respected, generally UKAS accredited, laboratories. Applied Geology can therefore not be held responsible for the testing carried out.

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