**Lavaflow**

# Proposed Development of a Sporting Complex for Boston United FC

**Boston, Lincolnshire**

**Document 2: Report on Site Investigation**

**August 2004**

**DATE ISSUED:** August 2004
**JOB NUMBER:** NL06842
**REPORT NUMBER:** J01

**CLIENT'S REFERENCE:**

**LAVAFLOW**

**Proposed Development of a Sporting Complex for Boston United FC**

**Report on Site Investigation**

**PREPARED BY:**

P D Shelton Principal Engineering Geologist

**APPROVED BY:**

R K Evans Technical Director

## CONTENTS



## APPENDICES



## DRAWINGS

# 1. INTRODUCTION

Wardell Armstrong LLP have been commissioned by Larvaflow to carry out intrusive site investigations at a site adjacent to the former aerodrome at Boston, Lincolnshire.

The scope of works has been established by a consideration of the proposed layout of the development shown on information provided by the Client. It is understood that the site has not been subject to any previous development, except farming and drainage and can therefore, for the purpose of development consideration, be described as greenfield.

The elements of this investigation have included the construction of cable percussion boreholes, insitu soil sampling and testing, laboratory testing and recording of local groundwater and soil gas conditions.

This report describes the intrusive site investigation works; it includes an assessment of the issues relating to geotechnical and contamination aspects of the proposed development.

## 2. SITE LOCATION AND DESCRIPTION

The site is located on the northern side of the A1121, to the west of Boston town centre. The site includes parts of the former Boston Aerodrome within the Wybarton Fen district (see drawing No NL06842/06).

The site presently contains no above ground structures. Land use in this area is predominantly arable farming, however, at the time of the investigation the site was fallow. General photographs of the site area are included in Appendix 1. The general site layout is shown on Drawing NL06842/07.

The site is bounded to the west, north and east by man-made drainage ditches. These have been designed (historically) to provide sustainable drainage for the immediate area, but are part of a well established drainage strategy for most of East Anglia.

To the south, the site is bounded by the A1121 highway running between Boston and Sleaford. The A1121 runs parallel to the South Forty Foot Drain, which constitutes the closest water course and is a major (albeit man-made) drainage feature.

## 3. GENERAL GEOLOGY AND MINING

The 1:63,360 scale British Geological Survey Sheet 128 (Solid and Drift Edition) covers the site and shows the site to be underlain by an unspecified thickness of recent drift deposits, named as the Barroway Drove Beds. The drift deposits are shown to overlie solid strata of Upper Jurassic age.

Previous investigations carried out on a nearby site have confirmed the presence of unconsolidated deposits, including soft clays, silts and peat to depths of between 4.0 and 6.0 metres. These borehole records show the unconsolidated soils to overlie stiff glacial till to borehole termination depths of between 13.0 and 15.4 metres below ground level.

There are no records of the site being within influencing distance of any form of surface quarrying or underground mining activities.

## 4. HYDROLOGY AND HYDROGEOLOGY

The site is located within the 'Fenlands' of East Anglia and is set at a relatively low elevation, 3.0 to 4.0 metres aOD.

Groundwater is expected at relatively shallow depth, but is generally controlled by a systematic network of ditches leading to larger, will developed 'man-made' drains. The closest major drain is the South Forty Foot Drain located adjacent to the A1121 at the southern end of the site.

It is considered that as well as the network of open peripheral ditches, networks of covered field drainage are also likely to be present at shallow depth beneath the agricultural fields.

# 5. INTRUSIVE INVESTIGATIONS

Intrusive site investigations were carried out during June and July 2004 by May Gurney, and comprised cable percussion boreholes and borehole groundwater and soil gas monitors. Details concerning these operations are included below.

## 5.1 Cable Percussion Boreholes

Between 5 and 8 July 2004, ten cable percussion boreholes were constructed to depths of between 10.0 and 13.0 metres below ground level at the locations shown on Drawing NL06842/07. Standard cable percussion boring equipment and procedures were employed producing 150mm diameter boreholes.

Open drive undisturbed U100 samples were taken from the boreholes within cohesive horizons.

Disturbed samples were taken at close intervals throughout boring in order to give a comprehensive record of strata encountered.

Standard Penetration Tests (SPTs) were carried out generally at 1.0 metre intervals (or alternately with U100 samples) during cable percussion boring. Tests were performed in accordance with the recommendations included in British Standard BS 1377:1990. In gravelly or hard soils, or where cobbles or boulders were expected, the split tube sampler was replaced with a 60° apex cone. The number of blows for 300mm penetration is given as 'N' values on the Borehole Record at the appropriate depths. Where a penetration of 300mm could not be achieved, the borehole records show the number of blows for the indicated depth of penetration.

Careful attention was paid during boring to determine whether groundwater existed through the strata penetrated.

The engineering Borehole Records were produced in general accordance with the procedures included in British Standard BS 5930:1999 and are included in Appendix 2. A graphical interpretation of the results of SPTs is included in Appendix 3.

## 5.2 Soil Gas Monitoring Installation

Soil gas and groundwater monitoring standpipes were fitted in four of the boreholes (Boreholes BH 5, 7, 9 and 10). The installations comprised a 50mm diameter plastic tube extending to a depth of 7.0 metres below ground level. Each monitoring tube was perforated along its length to a height of 1.0 metres below ground level, and surrounded with clean gravel. The upper metre comprised a bentonite seal, overlain by concrete. The installations were fitted with gas control valves and protective headworks.

The concentrations of carbon dioxide, methane and oxygen have been recorded following installation on one occasion. The gas concentrations were measured using a Geotechnical Instruments GA 90 infra-red triple gas analyser. The barometric pressure and weather conditions were noted during the gas monitoring and the results are included in Appendix 3.

# 6. LABORATORY TESTING

Laboratory testing comprised both geotechnical and contamination tests as detailed below.

## 6.1 Geotechnical Laboratory Testing

Samples recovered from the boreholes were tested in accordance with the recommendations of British Standard BS 1377:1990 "Methods of Tests for Soils for Civil Engineering Purposes". These tests are listed below and the results of laboratory testing are summarised in Appendix 4.

Geotechnical laboratory testing of soils was undertaken by May Gurney

***Classification***

*Natural Moisture Content*

The natural moisture content of 50 samples was determined. The results are reported as the percentage moisture content with respect to the dry weight of soil used in each test. The results of testing are shown on the Laboratory Testing Summary Sheet in Appendix 4.

*Atterberg Limit Tests*

In order to establish the consistency of the soils, 15 samples were tested to determine their Liquid and Plastic Limits and Plasticity Indices. The results are quoted as the percentage moisture with respect to the dry weight of soil used in each test. The results of testing are shown on the Laboratory Testing Summary Sheet in Appendix 4.

*Organic Matter Content*

The percentage weight of organic matter in 3 samples collected from peaty horizons within the upper unconsolidated deposits have been determined. The results of testing are shown on the Laboratory Testing Summary Sheet in Appendix 4.

***Mechanical Analysis***

The particle size distribution of 4 samples of the granular glacial deposits encountered at the base of the Barroway Drove Beds has been determined. The results of the analyses are included in Appendix 4.

*Consolidation Tests*

Multi-stage oedometer consolidation tests have been carried out on 2 undisturbed samples of Barroway Drove Beds and 2 samples of the overconsolidated glacial till materials. The results of testing are included in Appendix 4.

*Shear Strength Tests*

Quick undrained strength tests have been carried out on 5 undisturbed samples of the Barroway Drove Beds, and 2 samples of the overconsolidated glacial till materials. The results of testing are included in Appendix 4.

Where it has not been possible to extrude samples of the very soft Barroway Drove Beds for the purpose of undisturbed shear strength or consolidation testings an indication of shear strength has been obtained using vane testing methods (11 tests).

*Chemical Testing*

Chemical analyses have been carried out on 18 samples of the soils to determine pH and soluble sulphate content. The results are included in the Laboratory Testing Summary Sheet in Appendix 4.

Further chemical testing are included in the Contamination Testing Summary Sheet, also included in Appendix 4.

## 6.2 Contamination Testing

Six samples of the near surface soil deposits were analysed for the standard set of determinands proposed by the Interdepartmental Committee for the Redevelopment of Contaminated land (ICRCL).

Contamination laboratory testing of soil samples was undertaken by May Gurney.

These determinands included: Sulphides, Total Cyanides, Phenols, Total Sulphates, Toluene Extractable Matter, Total Arsenic, Total Cadmium, Total Chromium, Total Copper, Total Lead, Total Mercury, Total Nickel, Total Zinc, Total Selenium, Elemental Sulphur, Water Soluble Boron, Poly-aromatic Hydrocarbons (PAH), and pH. The results of testing are included in Appendix 4.

Four samples of groundwater collected from Boreholes BH 5, 7, 9 and 11, following the fieldwork stage of the investigation, have been tested for a selected suite of determinands. This suite includes pollutants derived from both industrial and agricultural activities. Contamination laboratory testing of groundwater samples was undertaken by Ceram Research. The results are included in Appendix 4.

## 7. GROUND CONDITIONS

The strata encountered in the boreholes were largely as expected and comprised surface agricultural soils overlying poorly consolidated alluvial/fenland deposits. The latter were encountered above overconsolidated glacial till.

A description of these strata are included below. A summary of geotechnical properties of the strata are included in Table 1 (Page 13).

### 7.1 Topsoil and Made Ground

Agricultural practices have resulted in the formation of an upper, disturbed layer of soils over the site. This upper layer is distinguishable from underlying undisturbed soils only by texture (they generally have a pseudo-granular appearance) and include rootlets and animal burrows. At many sites, this agricultural topsoil layer is only a few tens of centimetres thick. However, at this site, borehole records have indicated these to extend to depth of up to 0.80 metres thick.

Made Ground was not recorded at any of the borehole locations.

### 7.2 Unconsolidated Soil Deposits

Beneath the surface agricultural soils, unconsolidated soils were encountered in all boreholes to depths of between 3.30 and 4.80 metres (average 3.9 metres) below ground level. These are believed to belong to the Barroway Drove Beds referred to in Section 3.0. The unconsolidated soils can be described generally as soft grey and brown mottled sandy clay, and very soft and soft grey fine sandy silt/ loose silty fine sand with organic traces and bands. Some sub-angular and sub-rounded flint gravel was noted at depth. Upper layers of the unconsolidated soils are described as ‘firm’, which indicates a degree of desiccation, common in drained alluvial soils.

The results of standard penetration tests carried out during the fieldwork consistently indicated ‘very soft’ conditions, with the split spoon sampler falling under its own weight on most occasions. Laboratory tests gave measured undrained shear strength results of between 5 and 55 $kN/m^2$. The average soil shear strength is about 32 $kN/m^2$ for the clayey soils, but less than 10 $kN/m^2$ in the very soft silty beds.

Classification testing indicated the unconsolidated soils to have generally high moisture contents between 21 and 45%. The lower results are believed to reflect a degree of desiccated within the upper 1.0 to 1.50 metre thick soil section. This is roughly consistent with the thickness of soils sitting above the general groundwater level (see Section 7.4).

The results of Atterberg limit tests indicate the Barroway Drove Beds to be of ‘low’ and ‘intermediate’ plasticity, as defined by British Standard BS 5930:1999..

Horizons within the unconsolidated upper soils include variable organic contents. Where soil descriptions have indicated organic soils, subsequent testing of selected samples have confirmed significant organic content in the range 0.73 to 1.48%. While these results are significant, they should not be taken to represent the unconsolidated soils as a whole.

The results of consolidation testing have confirmed these to be of high compressibility, with coefficients of compressibility of between 0.45 and 0.59 $m^2$/MN.

## 7.3 Glacial Deposits

*Granular Deposits*

Beneath the unconsolidated soil deposits (Barroway Drove Beds), a layer of thin granular sand and gravel interbedded with firm brown clay with flint gravel was encountered at all borehole positions. The thickness of the granular layer is reported to be between about 0.5 and 1.9 metres thick. While borehole investigations have confirmed that this layer is persistent across the site, it is not believed that it forms a significant horizon with respect to the proposed development.

The results of standard penetration testing (SPT) indicate ‘N’ values of between 5 and 18, indicating loose to medium dense conditions. However, this layer is relatively thin and it is possible that the test results could include weaker (and/or more compact) deposits within or between the test sections.

*Glacial Till*

Glacial till was encountered at depths of between 4.8 and 5.3 metres below ground level (average about 5.0 metres). For the most part, the glacial till can be described as stiff and very stiff grey sandy clay with gravel and cobbles of flint and chalk fragments.

The results of the SPT carried out during the fieldwork indicated a progressively increasing shear strength, with depth. The results of SPTs are shown in Appendix 3 for all materials. The results indicate a generally high inferred shear strength for the glacial till, greater than 100 kN/m². Locally, low SPT results are indicated close to the top of the glacial till layer, increasing with depth. This may reflect local softening of the glacial till as a result of weathering.

Laboratory testing for soil moisture content and soil classification indicate typical values for overconsolidated glacial till. These show generally low moisture contents and low plasticity.

The results of consolidation testing have confirmed these to be of medium compressibility, with coefficients of compressibility of between 0.16 and 0.26 m²/MN.

### 7.4 Groundwater

Groundwater was not recorded in any of the boreholes during the course of the fieldwork. However, measurements in standpipes formed as part of the investigations have subsequently indicated standing groundwater levels at relatively shallow depth (0.7 to 1.2 metres). Results of groundwater monitoring are included in Appendix 3.

| TABLE 1 SUMMARY OF GEOTECHNICAL PROPERTIES | | | |
|---|---|---|---|
| **Parameter** | **Soft Clay** | **Silt** | **Glacial Till** |
| **Thickness (m)** | 3.5 – 4.8 (3.9) | | - |
| **Depth to top of horizon (m)** | - | | 4.8 – 5.3 (5.0) |
| **SPT 'N' value** | 1-3 (All results) | 1-3 (All results) | 18 - >100 (see Appendix 3) |
| **Undrained shear strength (kPa)** | 15-55 (32) | 5-17 (10) | 78-157 (108) |
| **Moisture Content (%)** | 25-43 (31) | 21-45 (33) | 13-25 (18) |
| **Liquid limit (%)** | 35-52 (45) | 50 | 30-43 (37) |
| **Plasticity index (%)** | 17-25 (22) | 25 | 13-23 (19) |
| **Bulk density (Mg/m$^3$)** | 1.812-1.972 (1.887) | 1.734 | 2.128-2.132 (2.130) |
| **Coefficient of Compressibility m$^2$/MN** | 0.45 (desiccat6ed) – 0.59 | | 0.16 – 0.26 |
| **Sulphate content $SO_3$ (acid soluble) ppm (g/l)** | 0.04-0.47 (0.18) | 0.07-0.35 (0.18) | 0.13-0.51 (0.29) |
| **pH** | 7.5-7.9 (7.7) | 7.6-7.7 (7.7) | 7.8-8.8 (8.3) |
| **Organic content** | 0.73 – 1.48 (1.10) | | |

# 8. DEVELOPMENT CONSIDERATIONS

It is understood that it is proposed to redevelop the whole of the site as a sporting complex associated with Boston United Football Club. This complex will include:

- a new stadium, including surrounding spectator seating areas;
- a training pitch, with an independent viewing stand;
- a hotel with associated car parking and hardstanding;
- other administrative buildings.

The proposed development layout, along with site investigation positions is shown on drawing No NL06842/02.

## 8.1 Contamination Issues

The historical research has shown that the site can, for the most part, be categorised as 'greenfield'.

An assessment of potential contamination issues has indicated the site to be of low risk.

Six soil samples obtained from upper consolidated deposits were chemically analysed for the determinands associated with the Interdepartmental Committee for the Redevelopment of Contaminated Land (ICRCL), Guidance Note 59/83, 2n[d] Edition, 1987. In addition, four samples of groundwater collected at relatively shallow depth, have been tested for excess heavy metal concentrations.

The results of testing have been assessed in accordance with several criteria including:

- ICRCL guidance;
- CLEA human health standards;
- EA guidelines on contamination threats to controlled water.

For Group A contaminants (contaminants which may pose hazards to health, including: arsenic, cadmium, chromium, lead, selenium and mercury), ICRCL 'Trigger Concentrations' are only available for end uses of 'Domestic Gardens and Allotments' and 'Parks, Playing Fields and Open Spaces'. The percentages of samples from which test results exceed these levels are summarised below.

| Table 2 | Percentage of Samples Tested Having Concentrations Greater that the 'Trigger Concentrations' | |
|---|---|---|
| **Determinand (Group A)** | **Domestic Gardens and Allotments** | **Parks, Playing Fields and Open Spaces** |
| **Arsenic** | 100% | 0% |
| **Cadmium** | 0% | 0% |
| **Chromium (Total)** | 0% | 0% |
| **Lead** | 0% | 0% |
| **Selenium** | 0% | 0% |
| **Mercury** | 0% | 0% |

The results indicate that of the Group A contaminants, only elevated levels of arsenic were recorded. The results indicate that while arsenic concentrations in the sub-soils may exceed previous stringent guidelines, they are lower than currently accepted levels for the proposed type of development.

It is concluded that the level of Group A contaminants would not have an effect on the proposed development which would be covered in buildings and hardcover. It should be noted that no samples of natural soils contained Group A contaminants above 'Threshold' trigger concentrations.

Notwithstanding the above, all site operations involving earthworks should be performed with due regard to ensuring the safety of site construction staff and the general public, including the establishment of COSHH procedures covering the identified contaminants. These should be incorporated into the Health and Safety Plan for the project in accordance with the CDM regulations.

Tests were also performed to determine the concentrations of the Group B contaminants (contaminants which are phytotoxic but not normally hazardous to health). The results have been summarised below in a similar manner to the Group A contaminants. In this case, however, no distinction is made regarding the end use of the site. 'Trigger Concentrations' therefore may refer to any site where plants are to be grown.

**Table 3**

| **Determinand (Group B)** | **Percentage of Samples Tested Having Concentrations Greater that the 'Trigger Concentrations'** |
|---|---|
| **Boron (water sol.)** | 0% |
| **Copper** | 0% |
| **Nickel** | 0% |
| **Zinc** | 0% |

The analyses indicated the presence of elevated (not grossly) levels of metals including copper, nickel and boron.

The results of soil contamination testing have also been interpreted in respect of the risk posed to potential site users and/or occupiers. This type of assessment makes use of Soil Guideline Values (SGV). The SGVs can only be interpreted with regard to protection of human health and do not take into consideration the potential for groundwater and surface water contamination. At present, only seven SGVs are currently published:

- arsenic;
- cadmium;
- chromium;
- selenium;
- nickel;
- lead;
- inorganic mercury.

Where there has been no SGV published for a contaminant, professional judgement has been used along with reference to other resources such as the former ICRCL guidelines and the Dutch Intervention Values (DIV) to determine the possible significance of that contaminant.

Where levels of contaminant exceed the SGV, then consideration should be given to whether further site investigation and sampling is required or remediation of the site is necessary.

The results of contaminant testing of soils are summarised in Table 3.

| **Table 4** – Summary of Chemical Analysis of Soil Samples | | | | |
|---|---|---|---|---|
| Determinand | Range | SGV / ICRCL Mg/kg | No. of Samples | No. of Exceedences |
| Arsenic | 11 – 23 | 500* | 6 | 0 |
| Cadmium | <0.1 – 0.1 | 1400* | 6 | 0 |
| Chromium | 12 – 29 | 5000* | 6 | 0 |
| Copper | 8.5 – 14 | 130* | 6 | 0 |
| Lead | 8.4 – 15 | 750* | 6 | 0 |
| Mercury | <0.1 | 480* | 6 | 0 |
| Phenols (total) | <0.3 | 5* (3) | 6 | 0 |
| Nickel | 19 – 29 | 5000* | 6 | 0 |
| PH | 7.46 – 8.84 | N/A | 24 | 0 |
| Selenium | <0.1 – 0.2 | 8000* | 6 | 0 |
| Sulphide – Acid Soluble | <0.5 – 65 | 250** | 6 | 0 |
| Total Cyanide | <0.5 | 250** (2) | 6 | 0 |
| Total Sulphate % | 0.05 – 65 | N/A | 6 | 0 |
| Water Soluble Boron | 2.5 – 3.5 | 3** | 6 | 3 |
| Water Soluble Sulphate (g/l) | 0.04 – 0.51 | N/A | 19 | 0 |
| Zinc | 20 – 61 | 300* | 6 | 0 |
| PAH | <10 | 50* (3) | 6 | 0 |
| Sulphur | <50 | | 6 | 0 |
| Thiocyanate | <1 - 19 | 50* (3) | 6 | 0 |

* SGV
** Former ICRCL Threshold
*** DIV
NA not applicable
NL no limit
(2) Due to the absence of a guideline value for total cyanide, the more conservative former ICRCL threshold value for complex cyanides of 250mg/kg has been used
(3) Former ICRCL threshold values for domestic gardens and allotments used in the absence of relative SGV's

*Groundwater*

Following the completion of site works, groundwater levels have been measured in four of the boreholes. These measurements confirm the presence of high level groundwater in the general vicinity of the site.

Samples of water were taken from each of the standpipe installations. These samples were tested for a range of determinands associated with historic industrial and agricultural usage.

The results of testing have been compared with stringent United Kingdom Drinking Water Standards (UKDWS) and with Environmental Quality Standards EQS). The results and conclusions of these comparisons are included below in table 4.

**Table 5** – Results of Water Testing

| Determinand | Range (ppm) | UKDWS µg/l (ppm) | No. of samples | No. of exceedences |
|---|---|---|---|---|
| Arsenic | <0.05 | 10 (0.01) | 4 | - |
| Cadmium | <0.01 | 5 (0.005) | 4 | - |
| Copper | 0.08 – 0.13 | 2000 (2) | 4 | 0 |
| Chromium | 0.03 – 0.07 | 50 (0.05) | 4 | 3 (all minor) |
| Lead | 0.26 – 0.48 | 25 (0.025) | 4 | 4 |
| Mercury | <0.001 | 1 (0.001) | 4 | 0 |
| Selenium | <0.001 | 10 (0.01) | 4 | 0 |
| Zinc | 0.27 – 0.57 | 5000 (5) | 4 | 0 |
| Boron | 1 – 2 | 1000 (1) | 4 | 3 (all minor) |
| Nickel | 0.07 – 0.15 | 20 (0.02) | 4 | 4 |
| Sulphate | 485 – 1345 | 250,000 (250) | 4 | 0 |
| Solvent Extractable Matter | 1.2 – 2.1 | | 4 | - |
| Total Phenols | <0.05 | 0.5 (0.0005) | 4 | - |
| Total Cyanide | <0.1 | 50 (0.05) | 4 | - |
| Sulphide | <0.1 | - | 4 | 0 |
| pH | 6.7 – 6.8 | N/A | 4 | - |
| BOD | 1 – 7 | | 4 | - |
| Ammonia | 0.3 – 1.3 | | 4 | - |
| TPH | <0.5 – 0.7 | N/A | 4 | - |
| VOC | <0.05 | | 4 | - |
| Electrical Conductivity ($\mu s.cm^{-1}$) | 3780 – 9370 | | 4 | - |
| COD | <10 - 77 | | 4 | - |

Exceedences were noted for chromium (minor), lead, boron (minor) and nickel. It is not certain where these contaminants have originated, but it is clearly not from any ongoing site operations. It is not expected that the groundwater will be used as a potable source in the near future. No action is considered necessary with respect to groundwater quality for the purposes of the development.

### 8.2 Sulphate Attack on Buried Concrete

In 2001, new guidance was issued by BRE on the design of concrete mixes in aggressive ground with BRE Special Digest 1 “Concrete in Aggressive Ground” replacing the former BRE Digest 353, 1991 “Sulphate and acid resistance of concrete in the ground”.

The new system requires as a starting point that sites are classified depending on the composition of the near surface strata and former site usage. These classes are described in Part 1 of the guidance “Assessing the aggressive chemical environment”, and can be summarised as follows:

- all sites (except for those subject to Brownfield development or containing pyrite);
- brownfield sites;
- pyritic ground (ground containing pyrite which, if disturbed, may oxidise to sulphates).

BRE Special Digest 1, Part 1, then goes on to prescribe a regimen of testing depending on the site classification and the results of preliminary tests. Guidance to ‘designers’ on the precautions to be taken to protect concrete in contact with the ground are given depending on a judgement of the mobility of groundwater at the site.

In the case of the proposed sports complex site, the previous usage classifies the site as ‘Greenfield’.

The results of soluble sulphate content tests do not indicate excessively high sulphate contents in ground water samples. On the basis of these results, BRE Special Digest SD1 indicates a ‘Design Sulphate Class’ of DS-1. The results of pH tests indicate the groundwater and soils to be near neutral. Therefore the general site classification for the ‘Aggressive Chemical Environment for Concrete’ (ACEC) is AC-1s.

With regard to the final design of the concrete mix, this becomes the responsibility of the structural designer and is covered by BRE Special Digest 1, Part 2: “Specifying concrete and additional protective measures”. The designer must take into consideration the results of the ACEC site classification, but some flexibility is permitted on the basis of other construction issues.

## 8.3 Gas Hazard

To date, the results of gas monitoring from borehole installations (Appendix 4) have recorded no methane. Borehole BH7 has detected slightly elevated carbon dioxide (2.8%), and corresponding slightly depressed oxygen (15.4%) levels.

It is considered likely that the slightly elevated levels of carbon dioxide and depressed oxygen are the results of the natural, aerobic degradation of small quantities of organic matter (possibly oils) contained within the soft gravelly clay Made Ground deposits overlying the solid strata. Although methane has not been detected in the borehole monitoring, it is also possible that conditions of anaerobic decay of organic matter may result in small quantities of methane generation.

In the light of the above and current guidance for the construction of new developments on 'brownfield' sites, it is recommended that allowance should be made for providing the minimum protection against infiltration of soil gasses. More data may be required to confirm conclusions, but it is considered that as a minimum this protection should include:

- a minimum 1200 gauge 'Visqueen' (or equivalent) layer, lapped and taped at joints and wrapped around construction joints;

- the incorporation of interconnected gas collection pipes within granular sub-base leading to granular venting trenches at the boundaries of the structure; or

- substitution of pipework with proprietary drainage collection geotextiles.

## 8.4 Geotechnical Considerations

*Foundations*

In view of the very soft and compressible nature of the near surface unconsolidated soils (Borroway Drove Beds) it is not recommended that shallow spread footings are adopted for any of the built developments in this stratum. Given the thickness of the Borroway Drove Beds, it is considered that it would not be feasible to found structures at deeper levels utilising trench fill methods.

Consideration has been given to pre-treating the ground to improve its bearing characteristics.

Ground treatment using vibro-treatment methods is not considered to be appropriate for use at this site. The principle reason for this is that the very soft and compressible unconsolidated solid may not be able to provide adequate lateral support to store columns. Under these circumstances, columns may bulge on loading, resulting in excess vertical settlement.

Dynamic compaction methods are generally considered to be unsuitable in soft, alluvial type soils.

Pre-consolidation using surcharge could be effective at this site, however, it could also be very time consuming and require the import and re-export of fill materials.

Given the proposed type of developments, it is recommended that consideration is given to constructing all above ground structures off piled foundations. Conventional bored cast-insitu (continuous flight auger, CFA) piles would be appropriate for the ground conditions.

The range of types and sizes of proposed structures within the sports complex will result in similar variations in the required foundation support. This can be achieved using piles of different lengths, diameters and/or the use of pile groups. It is recommended that the advice of specialist piling contractors is sought to provide information on the working capacity of proprietary piling systems. Notwithstanding this, general guidance on likely working loads for a variety of pile diameters and lengths is included in Table 5.

The basis of this preliminary pile design can be summarised as follows:

- piles are formed by bored cast-insitu methods;
- no contribution is assumed from soft clays and silts of the Borrowdale Drove Beds, or from the cohesive/granular layers immediately above the stiff glacial till;
- a minimum penetration of five times the pile diameter into the bearing stratum;
- no allowance has been made for negative skin friction generated by consolidation of the Borroway Drove Beds.

| **Table 6**: Typical Working Pile Loads | | | |
|---|---|---|---|
| Pile Diameter | 200 mm | 400 mm | 600 mm |
| Minimum Working Pile Load (Based on 5 x Pile Diameter | 25<br>1.0 m penetration | 130<br>2.0 m penetration | 340<br>3.0 m penetration |
| Pile Load Based on Minimum Length + 2.0 metres | 75<br>3.0 m penetration | 250<br>4.0 m penetration | 530<br>5.0 m penetration |

It is understood that it is likely that site drainage needs will result in a requirement raise site levels by the importation of fill materials. The suitability of imported materials should form part of a separate study relating to site preparation works. However, where fill is placed over existing natural soils, then the weight of the fill will induce settlement of the existing compressible surface soils. These settlements will, in turn, result in a 'down-drag' (or negative skin friction) effect on adjacent piles. The values of working pile load indicated above should therefore be adjusted, where appropriate to take into consideration the effects of negative skin friction on pile design.

*Floor Slabs, Car Parking and Hard Standing*

For the purposes of all proposed construction, the existing surface soils should be regarded as providing a 'very weak' sub-grade. Organic top soil should be removed prior to development. It has been noted that in places, top soil can be up to 0.70 metres thick. Scarrification and re-compaction of the upper surfaces, after the removal of topsoil, can result in a surface that is suitable for the construction of formation levels for floor slabs, hard standings and car park areas, given appropriate sub-base/capping layer thicknesses. For the purposes of preliminary design, it is recommended that a CBR value of 1.5% is used where the formation level comprised natural or re-worked natural soils.

Where site levels are raised through the import of fill materials, then it will be appropriate to re-assess pavement requirements on the basis of laboratory or in-situ testing of imported materials.

Advice on the sub-grade drainage and strength requirements beneath sports playing surfaces should be sought from specialist designers.

# 9. CONCLUSIONS

Ground investigations have been carried out at the site of a proposed sporting complex for Boston United FC. This complex will include:

- a new stadium, including surrounding spectator seating areas;
- a training pitch, with an independent viewing stand;
- a hotel with associated car parking and hardstanding;

other administrative buildings.

The purpose of the investigation has been to obtain information to be used for the design of structural foundations, and other groundworks.

The site is presently unoccupied and is considered to be ‘greenfield’. The site is surrounded (and crossed) by man made drainage ditches.

The investigation comprised cable percussion boring, insitu testing and laboratory testing.

***Ground Conditions***

Made Ground is not present. Agricultural topsoil is present to a thickness of up to 0.80 metres. Natural superficial soils comprise recent alluvial (fenland) deposits, known locally as the Borowdale Drove Beds, overlying glacial till. The Borroway Drove Beds comprise an upper ‘crust’ of desiccated clay (to a depth of between about 1.0 and 1.5 metres) over very soft and soft fine sandy clay and silt (and very looses and loose clayey silty sand). The very soft soils terminated at depths of between 3.50 and 4.80 metres.

The Borroway Drove Beds were found to overly a variable layer (between 0.50 and 1.50 metres thick) of glacial sand and gravel interbedded with firm brown clay.

The glacial till was encountered from depths of between 4.80 and 5.30 metres below ground level. The till generally comprised a stiff and very stiff grey sandy clay with gravel and cobbles of flint and chalk fragments. The results of SPTs indicate that the undrained shear strength of the glacial till increases with depth.

The full thickness of the glacial till was not penetrated.

Standing groundwater was encountered in borehole standpipes following the fieldwork period. Water levels were generally between 0.70 and 1.20 metres below ground level.

***Contamination Issues***

Geochemical testing of soil samples indicated only a minor exceedence of soluble boron. Exceedences of chromium (minor), lead, boron (minor) and nickel were noted in groundwater samples.

It is not believed that these levels of soil and groundwater contaminants would have any influence on the proposed site development.

***Sulphate Attack on Buried Concrete***

The results of soluble sulphate content tests do not indicate excessively high sulphate contents in ground water samples. On the basis of these results, BRE Special Digest SD1 indicates a ‘Design Sulphate Class’ of DS-1. The results of pH tests indicate the groundwater and soils to be near neutral. Therefore the general site classification for the ‘Aggressive Chemical Environment for Concrete’ (ACEC) is AC-1s.

***Soil Gas Hazard***

The results of gas monitoring from borehole installations have recorded no methane. One borehole has detected slightly elevated carbon dioxide and corresponding slightly depressed oxygen levels. It has been recommended that minimum precautions are adopted to protect enclosed structures against infiltration of soil gases including:

- a minimum 1200 gauge 'Visqueen' (or equivalent) layer, lapped and taped at joints and wrapped around construction joints;
- the incorporation of interconnected gas collection pipes within granular sub-base leading to granular venting trenches at the boundaries of the structure; or
- substitution of pipework with proprietary drainage collection geotextiles.

***Geotechnical Issues***

In view of the very soft and compressible nature of the near surface unconsolidated soils (Borroway Drove Beds) it is not recommended that shallow spread footings are adopted for any of the built developments in this stratum. Although consideration has been given to employing ground treatment methods including vibro-methods, dynamic compaction and surcharge, these have also been ruled out.

Recommendations have been provided to support structural units on piled foundations. Some general guidance on pile sizes and working loads has been provided, but it is recommended that the advice of a specialist piling contractor is sought.

General guidance has been provided for the designof floor slabs, car parking and hardstandings.