Phase 2 Geo-environmental Assessment

Proposed Visitor Centre, Messingham Road, Bottesford, Scunthorpe, Lincolnshire

on behalf of

Mason Clark Associates & North Lincolnshire Council

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Prepared By [redacted]

Chris Charlton
BEng (Hons)
Graduate Geo-Environmental Engineer

[redacted]

Daniel Brunt
BSc (Hons) MSc CGeol FGS
Principal Environmental Engineer

Reviewed & Approved for Release By [redacted]

Jon M English
BSc(Hons) MIEnvSc MCIWEM C.WEM CEnv SiLC
Suitably Qualified Person

Opus International Consultants (UK) Ltd
Nottingham Office
Opus House, 21 Vivian Avenue
Nottingham, NG5 1AF
United Kingdom

Telephone: [redacted]
Facsimile: [redacted]

Date: 10th August 2017
Opus Reference: K-NC812.00_R2/1_CC
Status: Final
NQMS Declaration Reference: 0317-A1276

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Phase 2 Geo-Environmental Assessment for a Proposed Visitor Centre at Messingham Road, Bottesford, Scunthorpe, Lincolnshire

1 Introduction

1.1 Purpose

1.1.1 This report describes a Phase 2 geo-environmental assessment undertaken by Opus International Consultants (UK) Limited (Opus), on behalf of Mason Clark Associates and North Lincolnshire Council, at a site off Messingham Road, Bottesford, Scunthorpe in Lincolnshire. An instruction to carry out the works was received from Mason Clark Associates on 5th April 2017.

1.1.2 This report has been written in the context of the proposed development of the site by North Lincolnshire Council with a visitors centre. It is understood that the visitors centre is intended to encourage visitors to explore the Bottesford Beck and its wildlife.

1.1.3 The site has previously been subject to a Phase 1 Contamination Assessment (ref. K-NC812.00_R1/1_LMH) dated 9th March 2017 prepared by Opus which should be read in conjunction with this report.

1.1.4 The objectives of the Phase 2 geo-environmental assessment were to undertake the recommended scope of intrusive investigation works, as detailed within Section 9 of the Opus Phase 1 Contamination Assessment report. This comprises an assessment of soil contamination associated with the previous and current land uses of the site, together with a ground gas assessment in order to establish any likely environmental constraints to development. In addition, the information on the ground conditions obtained during the ground investigation works would also enable suitable methods of design and construction for foundations and floor slabs to be assessed for the proposed development. Further details on the proposed scope of works are discussed within Section 1.2 below.

1.1.5 Land contamination, or the possibility of it, is a material consideration of the town and country planning regime. This means that a planning authority has to consider the potential implications of contamination both when developing plans and when it is considering individual applications for planning permission. The National Planning Policy Framework (NPPF) says that planning policies and decisions should ensure that:

- The site is suitable for its new use taking account of ground conditions and land instability, including from natural hazards or former activities such as mining, pollution arising from previous uses and any proposals for mitigation including land remediation or impacts on the natural environment arising from that remediation;
- After remediation, as a minimum, land should not be capable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990; and
- Adequate site investigation information prepared by a competent person is presented.

1.1.6 Where a development is proposed, the NPPF states that it is the responsibility of the developer to ensure that issues of land contamination are appropriately considered, that remediation takes place (where necessary) and that the land is safe and 'suitable for use' i.e. the site is cleaned up to a level which is appropriate for the proposed end use.

1.1.7 It is understood that this Phase 2 Geo-environmental Assessment report is to be submitted to the Local Planning Authority in support of an application for planning permission or a planning condition discharge submission for the new visitor centre.

1.2 Scope of Work

1.2.1 The scope of work undertaken for the Phase 2 geo-environmental assessment was as follows:

- Review utility survey plans showing the positions of any public and private underground services at the site;
- Preparation of a health and safety method statement and risk assessment for the proposed site investigation works;
- One day of intrusive site investigation comprising window sample boreholes – including site supervision, sampling and logging by a suitably experienced Geo-environmental Engineer;
- Carry out appropriate chemical analysis and geotechnical testing on selected soil samples;
- Undertake ground gas monitoring from installed standpipes;
- Preparation of a revised conceptual site model incorporating the findings of the intrusive investigation and the identification of potential and significant contaminant linkages;
- Prepare an interpretative report including Tier 1 human health and controlled waters risk assessment and a generic ground gas risk assessment.

1.3 National Quality Mark Scheme

1.3.1 The Phase 2 contamination assessment content of this report has been produced in accordance with the National Quality Mark Scheme for Land Contamination Management (NQMS) and has therefore been reviewed and approved by a registered Suitably Qualified and Experienced Person (SQP). The signed NQMS SQP Declaration of Document Adequacy is enclosed in Appendix A.

1.3.2 During the preparation of this report, reference has been made to the following guidance on undertaking preliminary risk assessments on land potentially affected by contamination:

- Environment Agency Contaminated Land Report 11 'Model Procedures for the Management of Land Contamination' 2004 (CLR 11);
- Yorkshire and Lincolnshire Pollution Advisory Group (YALPAG) 'Development on Land Affected by Contamination – Technical Guidance for Developers, Landowners and Consultants' Version 8.2 – February 2017.

1.4 Limitations

1.4.1 This report has been produced on behalf of the Client, Mason Clark Associates and North Lincolnshire Council, and no responsibility is accepted to any Third Party for all or any part. This report should not be relied upon or transferred to any other parties without the express written authorisation of Opus. If any unauthorised Third Party comes into possession of this report, they rely on it at their own risk and the authors owe them no duty of care or skill. Opus disclaims any responsibility to the Client and others in respect of any matters outside the scope of the above Contract.

1.4.2 This report has been prepared by Opus with all reasonable skill and care within the terms of the Contract with the Client, and taking account of the information made available by the Client, as well as the manpower and resources devoted to it by agreement with the Client.

1.4.3 The findings and opinions conveyed via this report are based on information obtained from a variety of sources, as detailed, which Opus believes are reliable. Nevertheless, Opus cannot and does not guarantee the authenticity or reliability of the information it has relied upon from these sources.

1.4.4 Whilst this report may express an opinion on the possible configuration of strata, contaminants or gases between or beyond exploratory hole positions 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 its accuracy.

1.4.5 The comments on groundwater and ground gas conditions are based on observations made at the time of the investigation. It should be noted, however, that groundwater and ground gas levels may vary from those reported due to seasonal or other effects.

1.4.6 The plans enclosed in this report should not be used for scaling purposes.

2 Regulatory Liaison

2.1 It was recommended in the Phase 1 Contamination Assessment report that, prior to commencing the Phase 2 intrusive investigation, the Phase 1 desk study report should be submitted to the Contaminated Land Officer at North Lincolnshire Council in order to gain approval of the findings and recommendations for the Phase 2 works.

2.2 This consultation with the Contaminated Land Officer has been carried out and the comments on the Phase 1 Contamination Assessment report are contained within an internal memorandum between departments at North Lincolnshire Council, a copy of which is presented in Appendix B of this report. A summary of the Contaminated Land Officer's comments are provided below:

- The Phase 1 report has been checked for quality by using the National Quality Mark Scheme and a Registered Suitably Qualified and Experienced Person (Jonathan English SQP0050). The Local Authority stated that this appears to have resulted in a good quality report being submitted on the Council's behalf;

- The Local Authority department is satisfied that the sampling density for soil contamination investigation, in line with BS10175:2011+A1:2013 is acceptable. The site has an area of 600m^2 and the proposal of between 2 and 4 boreholes all yield acceptable sampling densities;

- The Local Authority department is satisfied that the sampling density for gas monitoring wells is acceptable and in line with the guidance in CIRIA Report 659/665 as shown in table 5.1 in the Ground Gas Handbook. This is based on a moderate gas hazard and a low / moderate sensitivity of end use and the sampling density should be 50m as a maximum;

- The period and frequency of monitoring is unclear but it is anticipated to be six sets of readings over two months or six sets of readings over three months based on the Ground Gas Handbook, table 5.3 based on Wilson and Haines 2005;

- The Contaminated Land Officer also stated that they were willing to consider the application of the framework (CL:AIRE Research Bulletin RB 17 dated November 2012 entitled Pragmatic Approach to Ground Gas Risk Assessment) where it is applicable as an alternative to ground gas monitoring;

- In summary, the Local Authority state that they were appreciative of the high quality of the report and the detail it contained and are satisfied that the proposed scope of the Phase 2 assessment is adequate and will allow for the risk to the proposed visitors centre to be assessed.

3 Preliminary Conceptual Site Model

3.1 Introduction

3.1.1 As stated in the Phase 1 Contamination Assessment report, the assessment of potential ground contamination at the site has been based on the 'Suitable for Use' approach as advocated by Part 2A of the Environmental Protection Act 1990. The basis of the suitable for use approach is that land should be suitable for its current use and made suitable for any new use as official permission is given for that use. In addition, the requirements for remediation of contaminated land should be limited to the work necessary to prevent unacceptable risks to human health and the environment (including controlled waters) in relation to the current use, or officially permitted future use, of the land.

3.1.2 Under Part 2A of the Environmental Protection Act 1990 contaminated land is defined as land where **significant harm** is being caused or there is a **significant possibility of such harm** being caused, or **where significant pollution of controlled waters** is being caused, or there is a **significant possibility of such pollution** being caused. For significant harm to occur, a **significant contaminant linkage** must exist i.e. there must be a **contamination source**, a relevant **receptor** and a plausible **migration pathway**, by which the contaminant can cause significant harm to the receptor.

3.1.3 The National Planning Policy Framework 2012 states in Paragraph 120 that, with respect to the development of individual sites, '*where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner*'. Paragraph 121 notes that '*planning policies and decisions should also ensure that … the site is suitable for its new use taking account of ground conditions and land instability, including from natural hazards or former activities such as mining, pollution arising from previous uses and any proposals for mitigation including land remediation or impacts on the natural environment arising from that remediation'*. Paragraph 121 also states that '*after remediation, as a minimum, land should not be capable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990*'.

3.1.4 Following review of the desk study information and site reconnaissance (as detailed in the Phase 1 Contamination Assessment report), the following preliminary conceptual site model has been prepared below.

3.2 Potential Sources of Contamination

On-site Sources

3.2.1 The following potential **on-site** sources of ground contamination were identified from the Phase 1 desk study:

- Potential generation of ground gases from the decomposition of organic material in the event that peat is present in the underlying Alluvium. Potential ground gases include methane and carbon dioxide.

3.2.2 Where biodegradable materials are present in the ground, these can decompose to form potentially hazardous ground gases comprising methane and carbon dioxide. Methane is flammable in air and both methane and carbon dioxide are asphyxiants. These gases present a hazard if allowed to migrate, enter and accumulate in unventilated areas of buildings. The underlying Alluvium might constitute a source of ground gas, particularly if bands of peat are present.

3.2.3 As the site has never been developed and, based on the observations during the site reconnaissance, there is no evidence to suggest that contaminated fill or made ground has been deposited at the site, other than the materials used to construct the footpaths.

3.2.4 As there have never been any buildings or other structures present at the site, there is unlikely to be any contamination associated with historic or uncontrolled demolition practices.

3.2.5 Whilst the site was once under agricultural use as a field, no farm buildings or barns were present that could have been used for storage of pesticides / herbicides or for fuel storage facilities etc. Therefore no potentially significant sources of contamination associated with the former agricultural use of the land have been identified.

Off-site Sources

3.2.6 The following potential **off-site** sources of ground contamination have been identified from the Phase 1 desk study:

- Potential migration of landfill gas from the biodegradation of household waste within the former landfill located approximately 360m west of the site. Potential ground gases include methane and carbon dioxide.

3.2.7 Where waste material containing readily biodegradable material has been deposited on land, this gas generated is often referred to as landfill gas. Landfill gas from actively decomposing waste disposal sites typically comprises approximately two-thirds methane and one-third carbon dioxide. Methane is flammable in air at concentrations of between 5% and 15% by volume. Carbon dioxide and methane are both asphyxiants. These gases present a hazard to a development if allowed to enter and accumulate in unventilated areas of buildings.

3.2.8 Landfill gas from actively decomposing waste materials can migrate through unsaturated granular soils and fractured rock, travelling distances of up to several hundred metres. Where underground services or structures are present in the ground these can often act as high permeability conduits for the migration of landfill gas. Whereas the term landfill gas relates to gases occurring and generated from licensed, unlicensed, operating or non-operating landfill sites, 'ground gas' is a general term to include all gases occurring and generated within the ground, whether from made ground or natural deposits.

3.2.9 Given that the former landfill was filled sometime between the 1950's and 1980's, the rate of landfill gas generation would be expected to have already peaked and now be in decline. The landfill may be still be generating high concentrations of methane and carbon dioxide, however, the gas emission rate (i.e. the driving force for gas migration to occur) is anticipated to be low. Whilst the superficial deposits between the landfill and the site may be granular in nature and therefore represent a potential high permeability pathway for the migration of landfill gas, it is expected that the intervening distance of 360m is likely to be too far for gas migration to occur and significantly impact the site.

3.2.10 The former farm buildings and farm yard associated with Beck Farm are likely to have had sources of contamination present, such as the storage pesticides / herbicides and fuel storage tanks (most likely containing diesel). The land occupied by the Beck Farm buildings was redeveloped for housing in the 1980s and any contamination present may have been identified and remediated at the time. If not, given that Beck Farm was located approximately 40m to the north of the site, it is considered unlikely that significant contamination would have migrated down hydraulic gradient and significantly impacted the groundwater quality beneath the study site.

3.2.11 North Lincolnshire Council has advised that there was also a 250 gallon underground fuel tank at another (or replacement) Beck Farm, located approximately 280m northwest of the site. This tank is recorded to have been removed in 1976. Given the considerable distance to the site from this former tank, it is considered unlikely that hydrocarbon contamination will have migrated and significantly impacted the site under consideration.

3.2.12 The historic maps indicate the presence of two former sheep washes located adjacent to the Bottesford Beck, approximately 50m west and 245m northeast of the site respectively. It is understood that sheep washes were used by farmers to clean the fleece of sheep prior to their annual shearing, as opposed to sheep dips, which are a liquid formulation of insecticide and fungicide used by farmers to protect their sheep from infestation by parasites. Consequently the sheep washes are not considered to be a potential off-site source of contamination that could have significantly impacted the site.

3.2.13 The residential properties to the north and west and the public open space to the south and east of the site are not considered to represent significant potential sources of contamination.

3.2.14 The nearest potential contaminative trade to the site was situated approximately 20m north of the site and relates to pest and vermin control and is located at a residential property and therefore is not considered likely to be a significant potential off-site source of contamination.

3.2.15 A recorded pollution incident, comprising the release of oils into the Bottesford Beck 35m northeast and upstream of the site in 1996, was classified as a minor incident and therefore it is considered unlikely to have significantly impacted the site.

3.3 Receptors of Contamination

3.3.1 Receptors defined under Part 2A include:

- Human beings;
- Any ecological system or living organism forming part of such a system with specified areas of ecological importance;
- Property in the form of crops, domestically grown produce, livestock and pets;
- Property in the form of buildings;
- Controlled waters, such as surface water and groundwater.

3.3.2 Receptors are defined as human or non-human organisms that have the potential to experience adverse effects from direct or indirect exposure to contaminated material.

3.3.3 Migration pathways are defined as the courses chemicals take from a source to an exposed organism or receptor. The exposure pathway can be direct (i.e. stays within the same exposure media) or indirect where transport from one medium to another takes place.

3.3.4 The underlying superficial deposits of the Sutton Sand Formation (in north of the site) and Alluvium (in south of the site) are both classified by the Environment Agency as a Secondary A aquifer, indicating they are capable of supporting water supplies at local scale. Nevertheless the site is not located within a Groundwater Source Protection Zone and there are no groundwater abstractions within 1km of the site.

3.3.5 The Bottesford Brook is located approximately 8m south of the site and is a tributary of the River Trent which is located approximately 5.4km west of the site. There is one recorded surface water abstraction from the Bottesford Brook within 1km of the site located 990m west and downstream of the site. Taking the vulnerability of the underlying groundwater and adjacent surface watercourse into consideration, the environmental setting of the site is considered to be of moderate sensitivity.

3.3.6 The following potential human health and environmental receptors have been identified assuming the proposed visitor centre use of the site with associated landscaped areas:

- Future end users (staff and visitors to the centre);
- Plants grown in landscaped areas;
- Site construction and maintenance workers;
- Groundwater associated with the underlying Secondary A and B Aquifers;
- Surface water of the Bottesford Beck;
- Building materials.

3.4 Migration Pathways

3.4.1 The following potential migration pathways have been identified considering the proposed redevelopment of the site as a visitor centre:

- **Inhalation:** Human health can potentially be at risk from breathing dust and vapours from contaminated soil in the outdoor air and also the inhalation of fugitive dust inside buildings. Vapours from contaminated soil and groundwater can also migrate into buildings and be inhaled by the occupants.

- **Ingestion:** Human health can be potentially at risk from eating and swallowing contaminated soil and groundwater. Ingestion can also occur by deliberately eating contaminated soil or indirectly by eating and smoking with dirty hands etc., or by ingestion of fugitive dust.

- **Dermal Contact:** Human health can be potentially at risk from direct skin contact with contaminated soil and groundwater causing skin conditions such as dermatitis etc. and also dermal contact with fugitive dust inside buildings. Certain contaminants can be absorbed into the body through the skin or enter directly through open cuts and abrasions.

- **Uptake by Plants:** Some contaminants may be toxic to plants (phytotoxic) but not necessarily to human health at the same concentrations. Plant growth can also be adversely affected by ground gases.

- **Leaching:** Infiltration of water through soil can leach out soluble contaminants resulting in groundwater pollution.

- **Migration of Contaminated Water:** Depending on the permeability of ground conditions and any other man-made voids or preferential pathways, contaminated groundwater can potentially migrate laterally or vertically impacting adjacent surface and groundwater.

- **Migration of Ground Gas:** Ground gases may migrate laterally or vertically through permeable or voided ground and accumulate within unprotected buildings. Ground gas may also migrate along man made pathways following the route of least resistance e.g. along sewers and the surrounding granular bedding material.

- **Aggressive Attack:** Some buildings and materials can be damaged by direct contact with aggressive ground, for example sulphate attack on concrete and hydrocarbon attack on plastics.

3.5 Possible Contaminant Linkages

3.5.1 The desk study has identified the following possible contaminant linkages in consideration of the development proposals for the site. The term **possible contaminant linkage** (as used in this report), is defined as one that has the potential to represent unacceptable risks to human health or the environment but has not been identified through risk assessment. Where a possible contaminant linkage has been identified below, further investigation and risk assessment may be required to establish whether a **significant contaminant linkage** exists.

3.5.2 The identified possible contaminant linkages have also been subjected to qualitative risk assessment in line with guidance presented in NHBC and Environment Agency publication R&D 66 dated 2008:

Source	Pathway	Receptor	Consequence	Probability	Risk
Ground gases from Alluvium (if peat deposits present)	Generation, migration, accumulation inside the building	Future staff and visitors Neighbouring occupants	Severe	Low likelihood	Moderate
	Exposure during earthworks	Construction and maintenance workers	Severe	Low likelihood	Moderate
Ground gases (landfill 360m from site)	Migration and accumulation inside the building	Future staff and visitors Neighbouring occupants	Severe	Unlikely	Moderate / low
	Exposure during earthworks	Construction workers and maintenance	Severe	Unlikely	Moderate / low

3.5.3 The Preliminary Conceptual Site Model was also presented diagrammatically as the enclosed Drawing No. K-NC812.00_C403_1.

3.5.4 The possible contaminant linkage that is considered to present the greatest risk is the generation of methane and carbon dioxide gas from the underlying natural Alluvium. The level of risk will be dependent upon various factors, such as:

- Whether there are significant thicknesses of peat deposits present in the underlying Alluvium;

- Whether the peat is confined by an overlying low permeability clay layer; and

- Whether the peat will be penetrated by the foundations to the new building, for example if pile or vibro stone column foundations are employed, which could potentially present a preferential vertical pathway for gas to migrate beneath the building.

3.5.5 The risk posed to the development from the migration of landfill gas is considered to be slightly less than the underlying Alluvium, given the age of the waste, the considerable distance to the site (approximately 360m) and the absence of any known direct man-made migration pathways such as underground services.

3.5.6 The qualitative risk assessment undertaken indicates that further investigation is required in order to determine whether the possible contaminant linkages identified represent significant contaminant linkages or not, in accordance with the risk classification advice in R&D 66 which suggests:

- **Moderate risk** – further investigative work is normally required to clarify the risk and to determine the potential liability to site owner / occupier;
- **Low risk** – further investigative work (which is likely to be limited) to clarify the risk may be required.

3.5.7 It was therefore recommended in the Phase 1 desk study report that a Phase 2 contamination assessment, comprising an intrusive investigation with gas monitoring, should be undertaken in order to further assess the risks to the proposed development from the ingress of ground gas, from both the underlying Alluvium and also the migration of landfill gas from the former landfill located approximately 360m to the west of the site.

3.6 Uncertainty in the Preliminary Risk Assessment

3.6.1 The Phase 1 Contamination Assessment report concluded that soil contamination is unlikely to be present at the site, although this was based on an opinion formulated using various lines of evidence that contaminated made ground has never been placed on the land. If this opinion was found to be incorrect during the Phase 2 intrusive investigation works, it would alter the conceptual site model and the conclusions and recommendations of the preliminary risk assessment.

3.6.2 In order to mitigate against this potential uncertainty it is proposed that, the during the Phase 2 contamination assessment, the quality of the soil is inspected at the same time the exploratory holes are advanced for the ground gas investigation. In the unexpected event that potentially contaminated soil is encountered at the site then this can be submitted for chemical analysis to determine its quality and suitability for use.

4 Investigation Methodology

4.1 Underground Services

4.1.1 Prior to the intrusive investigation works, Opus were provided with underground services tracing surveys from the Client, and as such all exploratory holes were positioned to avoid known services. In addition, all proposed exploratory positions were also scanned using a cable avoidance tool and signal generator to check for the presence of live electricity or radio cables as a precautionary measure.

4.2 Exploratory Holes

4.2.1 The ground investigation comprised the advancement of 6 No. window sample boreholes (referenced WS01 to WS06 inclusive) which were drilled using a tracked window sampling rig.

4.2.2 The exploratory window sample holes were advanced on 12th May 2017 under the supervision of a suitably experienced Geo-environmental Engineer from Opus.

4.2.3 The window sample holes were drilled to depths ranging between 3.60m and 4.00m below existing ground level (begl).

4.2.4 Based on the desk study, the rationale for the positioning of the exploratory holes was to specifically target the proposed building footprint and to obtain general site coverage.

4.2.5 The window sample boreholes were logged on site by Opus in general accordance with BS 5930:2015 British Standards Institution 'Code of practice for ground investigations'. Soil samples were placed in appropriate laboratory supplied sampling vessels and kept refrigerated overnight until they were dispatched to the laboratory in a cool box containing frozen ice blocks by overnight courier.

4.2.6 Gas / groundwater monitoring standpipes were installed within two of the window sample holes, namely WS01 and WS04. The standpipes were constructed using 50mm diameter slotted HDPE well screen with a gravel surround and plain well casing with bentonite seal near surface. Each standpipe was fitted with a gas tap assembly and flush steel covers were placed to provide protection at ground level.

4.2.7 The locations of the exploratory holes are indicated on Drawing No. K-NC812.00_C404(R1). The exploratory hole logs are presented in Appendix C.

4.3 Headspace Testing

4.3.1 On site headspace testing of the soil samples collected from each of the window sample holes was carried out to screen samples for the presence of volatile organic compounds prior to laboratory testing. Measurements of volatile hydrocarbons in the air (headspace) between the soil and the container lid were recorded using a portable photo-ionisation detector (PID). The results of the headspace testing, expressed as parts per million (ppm) are presented (where detected) on the exploratory hole logs in Appendix C.

4.4 Gas and Groundwater Level Monitoring

4.4.1 In total, gas and groundwater monitoring has been carried out on six occasions over three calendar months (i.e. 19th May, 3rd, 15th, 22nd and 28th June and 6th July 2017) from two monitoring standpipes (WS01 and WS04).

4.4.2 Measurements of methane, carbon dioxide, oxygen, carbon monoxide and hydrogen sulphide, together with hexane vapour equivalent concentrations were taken using a Gas Data GFM435 MCERTS accredited infra-red gas analyser.

4.4.3 Atmospheric pressure and gas flow rates were recorded on each occasion and measurement of the groundwater levels was undertaken from each standpipe using an electronic dip meter during all monitoring visits.

4.4.4 The results of the gas and groundwater level monitoring are presented in Appendix D.

4.4.5 In addition to the above, falling head permeability testing was undertaken within the standpipes installed in window sample holes WS01 and WS04 on 19th May 2017 to enable an indicative assessment of permeability to be made. The results of the permeability tests were reported previously under separate cover.

4.5 Groundwater Monitoring

4.5.1 Measurement of the groundwater levels relative to the well cover were taken in each of the two standpipes installed at the site using an electronic dip meter. Groundwater level monitoring was undertaken from each standpipe during the six gas monitoring visits (as discussed above). The results of the groundwater level monitoring are reported on the tables enclosed within Appendix D.

4.5.2 A groundwater sample was collected from the monitoring well installed in WS01 on 4th June 2017. Prior to sampling, the well was purged using a dedicated Waterra disposable bailer. The aim was to purge three casing volumes of water from the monitoring well prior to collecting the groundwater sample on 3rd June 2017. However, there was insufficient recharge of the groundwater to enable three casing volumes of water to be purged from WS01 prior to sample collection and this well was noted to run dry and recharge very slowly. In view of this, the groundwater was left to recharge overnight, with further purging carried out on the morning of 4th June 2017. Due to the slow recharge, only 75% of the proposed three casing volumes were purged prior to sample collection. The groundwater collected during purging was placed in laboratory provided bottle ware and stored in a refrigerator overnight, then dispatched to the laboratory the following day by overnight courier in a cool box containing ice packs.

4.6 Chemical Analysis

4.6.1 Made Ground was identified in the exploratory holes during the fieldwork. Given that the source of this Made Ground was unknown, selected soil samples were subjected to chemical analysis for a range of commonly occurring potential contaminants. This analysis was carried out at the MCERTS / UKAS accredited laboratory of QTS Environmental Limited (QTS).

4.6.2 The following analyses were carried out on recovered soil samples:

- Heavy metals 6 No. samples
- Speciated polycyclic aromatic hydrocarbons (PAHs) 6 No. samples
- Fraction organic carbon (FOC) 6 No. samples
- Asbestos identification in soil samples 4 No. samples

4.6.3 The results of the chemical testing performed on the selected soil samples are presented in Appendix E.

4.7 Geotechnical Testing

4.7.1 As part of the geotechnical assessment at the site, soil samples were subjected to classification testing. This analysis was carried out at the MCERTS / UKAS accredited laboratories of QTS Environmental Ltd (QTS) and Geolabs Limited.

4.7.2 The following analyses were carried out on recovered soil samples:

- Total sulphur and total sulphate 3 No. samples
- Water soluble sulphate 3 No. samples
- pH 8 No. samples
- Atterberg Limits 3 No. samples
- Natural moisture content 3 No. samples

4.7.3 The results of the pH and sulphate testing are presented along with the chemical testing results in Appendix E. All other test results are presented in Appendix F.

5 Ground Conditions Encountered

5.1 Made Ground

5.1.1 Made Ground was encountered in all exploratory holes advanced at the site. The base of the Made Ground was proven in each of the window sample holes at depths ranging between 0.70m begl in WS03 and WS05 and 0.90m begl in WS06.

5.1.2 The Made Ground encountered can broadly be sub-divided into three main types of material based on the observed physical characteristics, as summarised below:

- Made Ground 'Topsoil'
- Made Ground 'Clay'
- Made Ground 'Concrete'

5.1.3 The Made Ground 'Topsoil' comprised dark brown clayey, silty, gravelly sand topsoil containing fragments of brick, concrete, limestone and quartzite. This material was encountered in all exploratory holes to a maximum depth of 0.90m begl in WS06.

5.1.4 The Made Ground 'Clay' comprised brown slightly silty to silty, slightly sandy, slightly gravelly to gravelly clay containing fragments of concrete, limestone and quartzite, with rare coal and wood. This material was only encountered beneath the Made Ground 'Topsoil' in WS03 and WS04 to depths of 0.70m and 0.75m begl respectively.

5.1.5 The Made Ground 'Concrete' was only encountered in WS04 at 0.75m begl to a depth of 0.85m begl.

5.2 Natural Strata

5.2.1 Natural strata was proven in all of the exploratory holes and is considered to represent Alluvium which is indicated on the geological mapping for the area to be present at the site.

5.2.2 The natural strata encountered can broadly be sub-divided into three main types of material based on the observed physical characteristics, as summarised below:

- 'Silty sandy clay'.
- 'Clayey silty sand'.
- 'Silty peaty sand'.
- 'Peat'.

5.2.3 The very soft consistency, brown, 'silty sandy clay' was encountered in all of the exploratory holes to a maximum depth of 1.60m begl (in WS01).

5.2.4 The orange-brown and grey, slightly 'clayey silty sand' (fine to coarse) was encountered in five of the exploratory holes, namely WS01 to WS05 inclusive to a maximum depth of 1.80m begl (in WS01).

5.2.5 The ‘silty peaty sand’ was typically described as grey, silty, fine to coarse sand containing peat or plant matter and this was encountered in all exploratory holes. The peat and organic / plant matter content varied between exploratory holes. This material was encountered to the base of each exploratory hole.

5.2.6 A layer of brown, sandy spongy to plastic, amorphous ‘peat’ was encountered in one of the window sample holes, i.e. WS04 between 1.80m and 2.80m begl.

5.3 Groundwater Observations

5.3.1 Groundwater was encountered in all of the exploratory holes on completion of drilling. The depths to groundwater were noted to range between 1.47m begl in WS02 to 1.88m begl in WS01.

5.3.2 During the subsequent groundwater level monitoring, groundwater was observed in both of the monitoring standpipes on each of the six monitoring visits. Resting groundwater levels were recorded to range between 1.54m (on 28th June 2017) to 1.69m begl (on 22nd June 2017) in WS01 and between 1.31m (on 6th July 2017) and 1.42m begl (on 22nd June 2017) in WS04.

5.4 Field Observations and Headspace Testing

5.4.1 Visual and / or olfactory evidence of contamination (such as hydrocarbons or asbestos) was not encountered in any of the exploratory holes advanced during the site investigation.

5.4.2 Headspace testing undertaken using a photo-ionisation detector (PID) on soil samples recovered from the window sample holes only recorded very low concentrations of VOCs, up to a maximum of 1.1ppm in WS02 at a depth of 1.30m begl in a sample of natural sand.

6 Human Health Risk Assessment

6.1 Assessment Criteria

6.1.1 The results of the chemical analysis on soil samples have been reviewed in accordance with the legislative framework and criteria set out in Appendix G. The results of the chemical analysis of soil samples have been compared to the following published generic assessment criteria (GAC) as compiled in Opus Tier 1 soil screening values (SSVs) Version 2016.1 dated 21st November 2016:

- Defra Category 4 Screening Levels (C4SLs);
- LQM / CIEH Suitable for Use Level (S4ULs).

6.1.2 The following general strata types were analysed:

Soil Type	No. of Samples Analysed
Made Ground 'Topsoil'	4
Made Ground 'Clay'	1
Alluvial Clay	1

6.1.3 It is understood that the site is proposed to be developed with a small single storey visitor centre building, along with surrounding areas of soft landscaping. In view of this, the assessment of the soil contamination results has been conducted assuming a standard CLEA commercial end use for the staff and maintenance workers at the visitors centre. In addition, the results have also been examined in relation to a standard CLEA public open space (public land near residential properties i.e. grassed area outside residential housing) end use in relation to the landscaped areas for the visitors to the building. If the land use proposals were to change, such as a different end use involving more sensitive receptors, then the risk assessment would require amendment.

6.1.4 There is an insufficient number of samples tested for metals and PAHs for the Made Ground material types and the natural Alluvial clay (i.e. less than five samples of each soil type) to allow meaningful statistical assessment in accordance with the CL:AIRE and CIEH document titled 'Guidance on Comparing Soil Contamination with a Critical Concentration' published in May 2008. The results of the soil laboratory testing undertaken on these material types have therefore been compared directly to their respective published assessment criteria.

6.1.5 A total of six soil samples were tested for fraction organic carbon (FOC). Different FOC contents have been calculated for each soil type where a FOC test was undertaken. For the purposes of the risk assessment the following soil organic matter (SOM) contents have therefore been assigned from the laboratory results:

Soil Type	Soil Organic Matter (%)	
	Mean Laboratory Result	Assigned
Made Ground 'Topsoil'	2.63	2.5
Made Ground 'Clay'	1.21	1
Alluvial Clay	3.10	2.5

6.2 Interpretation of Metals and PAH Results

Made Ground 'Topsoil'

6.2.1 The results of the laboratory testing for metals and PAHs undertaken on four samples of Made Ground 'Topsoil' and compared directly to the respective GAC indicate that the concentrations detected were all below their respective assessment criteria for both commercial and public open space end uses at 2.5% SOM.

6.2.2 In view of the above, the Made Ground 'Topsoil' is considered as being chemically suitable for retention near surface at the site from a protection of human health perspective.

Made Ground 'Clay'

6.2.3 The results of the laboratory testing for metals and PAHs undertaken on one sample of Made Ground 'Clay' and compared directly to the respective GAC indicate that the concentrations detected were all below their respective assessment criteria for both commercial and public open space end uses at 1% SOM.

6.2.4 In view of the above, the Made Ground 'Clay' is considered as being chemically suitable for retention near surface at the site from a protection of human health perspective.

Alluvial Clay

6.2.5 The results of the laboratory testing for metals and PAHs undertaken on one sample of the natural Alluvial 'Clay' and compared directly to the respective GAC indicate that the concentrations detected were all below their respective assessment criteria for both commercial and public open space end uses at 2.5% SOM, with the exception of the following:

- A benzo(b)fluoranthene concentration of 8.69mg/kg in WS01 at 1.00m begl exceeds the S4UL assessment criteria of 7.2mg/kg for a public open space land-use. The S4UL for a commercial end use (of 44mg/kg) has not been exceeded;

- A benzo(a)pyrene concentration of 6.32mg/kg in WS01 at 1.00m begl exceeds the S4UL assessment criteria of 5.7mg/kg for a public open space land-use. This benzo(a)pyrene concentration is below the C4SL of 10mg/kg for a public open space land-use. Furthermore, the S4UL or C4SL for a commercial end use (of 35mg/kg and 76mg/kg respectively) have also not been exceeded.

6.2.6 In view of the above, given that the PAH concentrations were recorded in a sample of natural Alluvial clay with no visual or olfactory evidence of contamination (such as by hydrocarbons or other obvious source of contamination), the laboratory were requested to inspect the sample for any obvious contamination and also carry out a re-test. The inspection of the sample confirmed the observations made by Opus during the logging and sampling of the soils on site. With regard to the re-test, this was carried out from a fresh sub-sample of the soil submitted for analysis (rather than re-testing the original extract) and the laboratory confirmed that a similar concentration was detected.

6.3 Interpretation of Asbestos Results

6.3.1 Three samples of the Made Ground 'Topsoil' and one sample of the Made Ground 'Clay' were submitted to the laboratory for asbestos identification analysis. Asbestos was not identified in any of the samples analysed.

6.4 Summary and Conclusions

6.4.1 The results of the chemical laboratory analysis undertaken on selected soil samples during this investigation indicate that the concentrations of the determinands detected are all below their respective human health generic assessment criteria, with the exception of two PAH compounds (i.e. benzo(a)pyrene and benzo(b)fluoranthene) in a sample of the natural clay in WS01 at 1.00m begl.

6.4.2 In view of the above, it is considered that there is potentially elevated PAH concentrations in the natural clay, possibly relating to a hotspot around WS01 although at this stage the lateral and vertical extent of the contaminated soil is unknown. Given that the elevated PAHs were detected in the natural Alluvial clay at depth, the source of the contamination may be attributed to historic natural events such as forest fires, rather than as a result of human activity.

6.4.3 It should be noted that the natural Alluvial clay in WS01 was encountered at a depth of 0.80m begl. The Alluvial clay soils in question in WS01 are situated beneath a layer of Made Ground 'Topsoil', a sample of which had been analysed at the laboratory and proven to contain only low concentrations of PAHs below their respective GAC. Elsewhere on site, the depth of the natural Alluvial clay was at least 0.70m begl, therefore it is considered that the notable PAH concentrations detected in the natural Alluvial clay are essentially encapsulated by a suitable thickness of overlying Made Ground 'Topsoil' which is considered to be chemically suitable for the proposed end use. Providing that the natural Alluvial clays (particularly around WS01) are encapsulated by a minimum 0.30m thickness of the Made Ground 'Topsoil' in soft landscaped areas upon completion of the development, it is considered that no remedial actions or further investigation is necessary.

7 Controlled Waters Risk Assessment

7.1 Introduction

7.1.1 According to the inspected published geological information, Alluvium and the Sutton Sand Formation are shown to be present on the site and these superficial deposits are underlain by the solid strata of the Scunthorpe Mudstone Formation. The site investigation encountered materials considered to represent the Alluvium in all of the exploratory hole locations at the site.

7.1.2 The Alluvium and the Sutton Sand Formation are classified by the Environment Agency as a Secondary A Aquifer, whilst the underlying Scunthorpe Mudstone Formation (not encountered in the exploratory holes drilled at the site) is classed as a Secondary B Aquifer. The site is not indicated to be within a Groundwater Source Protection Zone.

7.1.3 The closest surface water feature to the site is the Bottesford Beck which is located approximately 8m south of the site and flows in an easterly to westerly direction. The Bottesford Beck is a tributary of the River Trent.

7.1.4 Groundwater was encountered during the advancement of all of the exploratory holes, together with the subsequent groundwater level monitoring carried out in standpipes installed in two of the window sample holes. Resting groundwater levels were recorded to range between 1.31m to 1.69m begl.

7.2 Assessment Criteria

7.2.1 In England, the control of water pollution is the responsibility of the Environment Agency. The Environment Agency is responsible for monitoring, controlling and remedying pollution of “controlled waters”, which as detailed in S104 of the Water Resources Act 1991, include relevant territorial waters, coastal waters, inland fresh waters and groundwater. Enforcement powers are contained in S85 of the Water Resources Act 1991 under which “it is an offence to cause or knowingly permit any poisonous, noxious or polluting matter to enter controlled waters”.

7.2.2 The EC have issued several directives concerned with water quality, notably the Water Framework Directive 2000/60/EC (WFD) in December 2013 and the new Groundwater Directive (2006/118/EC), commonly referred to as the Groundwater Daughter Directive (GWDD). Member States now only have to define which substances are hazardous, all other pollutants being non-hazardous. Both hazardous substances and non-hazardous pollutants are subject to control. In 2015, the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 was published and came into force on 22nd December 2015 and introduces revised Environmental Quality Standards.

7.2.3 The WFD expanded the scope of water protection to all bodies of water, surface water and groundwater, with the aim of achieving ‘good status’ by 2015, however, it is understood that this has been extended to 2021. Assessment and management of water bodies (including groundwater) has been carried out on a River Basin District basis. The Directive sets out a series of environmental objectives which for groundwater are to:

- Implement measures to prevent or limit the input of pollutants into groundwater and to prevent deterioration of groundwater;

- Protect, enhance and restore all bodies of groundwater and ensure a balance between abstraction and recharge of groundwater, with the aim of achieving 'good groundwater status' by 2021 (previously 2015) except under certain special circumstances (see below);

- Implement measures to reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce the pollution of groundwater;

- Ensure compliance with the relevant standards and objectives by 2021 (previously 2015 – see below).

7.2.4 Less stringent objectives for specific bodies of water may be set where these are so affected by human activity or their natural condition is such that it would be unfeasible or disproportionately expensive to reach good status. The 2015 target date can be extended by Member States where there are reasonable grounds. It is understood that the target date has been extended to 2021, with further extensions only under exceptional circumstances.

7.2.5 Under Part 2A of the Environmental Protection Act 1990, land may be designated as "contaminated land" if significant pollution of controlled water is being, or there is a significant possibility of such pollution being caused. Clean-up of contaminated land can be enforced under Part 2A where contaminated land is determined under the regulations with costs recovered through the courts from the "appropriate person" (usually the polluter or landowner).

7.2.6 The results of the groundwater sample obtained from the monitoring standpipe installed by Opus in WS01 have been examined with reference to UK Environmental Quality Standards (EQS) which provide standards for a range of potential contaminants for the protection of aquatic life in inland waters, estuarine waters and marine waters. In the absence of EQS values the results have been compared to UK drinking water quality standards (DWQS) as prescribed in the Water Supply (Water Quality) Regulations 2000, although these quality standards are aimed at being achieved at the consumers tap after potable water treatment.

7.2.7 The results of the soils analysis have also been assessed in relation to the potential risks posed to controlled waters.

7.3 Interpretation of the Soil Results

Total PAHs

7.3.1 The concentrations of total PAHs in all six of the soil samples analysed were below 40mg/kg which is a trigger concentration that the Environment Agency often use as a 'rule of thumb' where concentrations above this usually require further risk assessment in order to determine if there is a potential risk to controlled waters, with the exception of one sample of natural Alluvial clay. A total PAH concentration of 68.8mg/kg was detected in the natural clay in WS01 at 1.00m begl.

7.3.2 In view of the above, it is considered that the majority of the soil concentrations detected are unlikely to pose a risk to controlled waters. However, it was considered that further investigation of the notable PAH concentration detected in WS01 was required to enable an assessment of the potential risks to controlled waters. A sample of the groundwater within the monitoring standpipe in WS01 was therefore collected and analysed at the laboratory for PAHs. The results of the groundwater analysis are discussed in Section 7.4 below.

Heavy Metals

7.3.3 The concentrations of heavy metals detected in the Made Ground and natural soils at the site are considered to be typical of uncontaminated soil. Therefore the potential risks to controlled waters from heavy metals are considered to be low.

7.4 Interpretation of Groundwater Results

7.4.1 The results of the groundwater PAH analysis have been compared directly with the respective EQS.

7.4.2 None of the 16 US EPA PAH compounds were detected at concentrations above the laboratory's analytical reporting limit of <0.01µg/l (<0.008µg/l for benzo(ghi)perylene).

7.4.3 The analytical results were all below the EQS maximum allowable concentration for inland surface water. In addition the EQS annual average for inland surface water was not exceeded by the analytical results, except in the case of fluoranthene (0.0063µg/l) and benzo(a)pyrene (0.00017µg/l) which were potentially exceeded by the analytical reporting limit of <0.01µg/l. The EQS for PAHs were revised in 2015 and in the case of fluoranthene and benzo(a)pyrene are considerably below the standard analytical detection limit of most laboratories and considered unlikely to be of a concern to the Environment Agency.

7.4.3 It is therefore concluded that the concentrations of PAHs detected in the groundwater sample from WS01 (where notable total concentrations were detected in the natural soils) are low and are unlikely to pose a risk to controlled waters.

7.5 Summary and Conclusions

7.5.1 In view of the above, it is considered that the notable PAH concentration detected in the soil sample in WS01 does not appear to pose a significant risk to controlled waters including the underlying groundwater or nearby Bottesford Beck and therefore remediation of these soils (such as excavation and disposal off-site) is not likely to be required from a protection of controlled waters perspective.

8 Ground Gas Risk Assessment

8.1 Assessment Criteria

8.1.1 Where waste material containing readily biodegradable material has been deposited on land, this gas generated is often referred to as landfill gas. Landfill gas from actively decomposing waste disposal sites typically comprises approximately two-thirds methane and one-third carbon dioxide. Methane is flammable in air at concentrations of between 5% and 15% by volume. Carbon dioxide and methane are both asphyxiants. In addition, methane and carbon dioxide may be generated by the degradation of hydrocarbons (including oils and solvents etc.) in the ground and also during the degradation of organic matter within natural drift deposits. These gases present a hazard to a development if allowed to enter and accumulate in unventilated areas of buildings.

8.1.2 Landfill gas from actively decomposing waste materials can migrate through unsaturated granular soils and fractured rock, travelling distances of up to several hundred metres. Where underground services or structures are present in the ground these can often act as high permeability conduits for the migration of landfill gas.

8.1.3 Whereas the term landfill gas relates to gases occurring and generated from licensed, unlicensed, operating or non-operating landfill sites, 'ground gas' is a general term to include all gases occurring and generated within the ground, whether from made ground or natural deposits. Consequently, ground gas concentrations and flow rates from Made Ground and natural deposits are typically much lower than for landfill gas generated from domestic waste landfill sites.

8.1.4 Guidance on the assessment of ground gas and the design of gas protection measures is detailed within the following documents:

- Construction Industry Research and Information Association (CIRIA) Report C665, entitled "Assessing Risks Posed by Hazardous Ground Gases to Buildings" dated December 2007;
- British Standard BS8485:2015 entitled 'Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings';
- BS8576:2013 entitled 'Guidance on investigations for ground gas – Permanent Gases and Volatile Organic Compounds (VOCs)';
- CIRIA Report C735 entitled 'Good practice on the testing and verification of protection systems for buildings against hazardous ground gases' dated 2014;
- Department of Environment, Transport and Regions (DETR) / Partners in Technology Research Report titled 'Passive Venting of Soil Gases Beneath Buildings';
- Building Research Establishment (BRE) Report BR211 entitled 'Radon: Guidance on Protective Measures for New Buildings' dated 2015.

8.1.5 The CIRIA C665 guidance contains the Modified Wilson and Card characterisation system which is appropriate for the proposed visitor centre building and combines the results of a qualitative assessment together with gas monitoring results to give a semi-quantitative estimate of risk for a site. The guidance suggests that the calculations should be undertaken for both methane and carbon dioxide and then the worst case value adopted. The higher the classification the greater the risk posed by the presence of gas.

8.1.6 The proposed visitor centre building at the site is understood to comprise a one-storey structure. The gas risk assessment undertaken using the Modified Wilson and Card characterisation system is summarised on the table in Appendix D.

8.1.7 The following potential sources of ground gas were identified from the Phase 1 desk study:

On-site

- Potential generation of ground gases from the decomposition of organic material present in the underlying Alluvium deposits.

Off-site

- Potential migration of landfill gas from the biodegradation of household waste within the former landfill located approximately 360m west of the site.

8.1.8 Organic materials considered to have the potential to biodegrade to generate ground gas comprised plant matter and / or peat within the alluvial silty sand within the drift deposits in each of the exploratory holes. A layer of peat alone was also encountered in WS04 (at 1.80 – 2.80m begl). However, these organic materials are generally considered to be predominantly slowly biodegradable, rather than readily putrescible and are therefore unlikely to generate significant quantities of ground gas.

8.1.9 With regard to the former landfill it is considered that, as it was filled sometime between the 1950's and 1980's, the rate of landfill gas generation would be expected to have already peaked and now be in decline. The landfill may be still be generating high concentrations of methane and carbon dioxide, however, the gas emission rate (i.e. the driving force for gas migration to occur) is anticipated to be low. Whilst the superficial deposits between the landfill and the site may be granular in nature and therefore represent a potential high permeability pathway for the migration of landfill gas, it is expected that the intervening distance of 360m is likely to be too far for gas migration to occur and significantly impact the site.

8.1.10 The possible contaminant linkage that is considered to present the greatest risk is the generation of methane and carbon dioxide gas from the underlying natural Alluvium. The level of risk will be dependent upon various factors, such as:

- Whether there are significant thicknesses of peat deposits present in the underlying Alluvium;
- Whether the peat is confined by an overlying low permeability clay layer; and
- Whether the peat will be penetrated by the foundations to the new building, for example if pile or vibro stone column foundations are employed, which could potentially present a preferential vertical pathway for gas to migrate beneath the building.

8.1.11 The risk posed to the development from the migration of landfill gas is considered to be slightly less than the underlying Alluvium, given the age of the waste, the considerable distance to the site (approximately 360m) and the absence of any known direct man-made migration pathways such as underground services.

8.1.12 Based on the conceptual site model, it is considered that the site corresponds with a low potential for ground gas generation. For the proposed development of a small visitor centre building with a sensitivity considered to be low to moderate, CIRIA C665 recommends at least six readings are required over two to three calendar months.

8.2 Gas Monitoring Results

8.2.1 To date, gas monitoring has been undertaken on six occasions over three calendar months in order to carry out an assessment of the ground gas regime (namely 19th May, 3rd, 15th, 22nd and 28th June and 6th July 2017) from two monitoring standpipes (WS01 and WS04) situated either beneath or close to the footprint of the proposed building. The results of the gas monitoring are enclosed in Appendix D. The locations of the gas monitoring points are indicated on Drawing No. K-NC812_C404 (1).

8.2.2 Concentrations of methane have not been detected in any of the monitoring standpipes on each of the six monitoring visits.

8.2.3 Concentrations of carbon dioxide were detected in each of the monitoring standpipes on each of the visits, up to a maximum concentration of 6.3% by volume in WS4 on 22nd June 2017. Carbon dioxide has been detected above 5% by volume on three additional occasions in WS4 on 15th and 28th June and 6th July 2017. All other carbon dioxide readings were lower than 5.0% by volume.

8.2.4 Carbon monoxide and hydrogen sulphide were not detected in either of the standpipes during the six monitoring visits.

8.2.5 Positive flow rates have not been detected at the site in any of the standpipes during the monitoring visit carried out.

8.2.6 Periods of rapidly falling atmospheric pressure are considered to be the optimum barometric conditions for gas emissions from the ground. All six of the monitoring visits were undertaken following periods of falling atmospheric pressure, with a relatively large fall of 10mb (from 1009mb to 999mb) being recorded on 28th June 2017 and also a fall of 8mb (from 1015mb to 1007mb) recorded on 22nd June 2017 respectively. The remaining falls in atmospheric pressure were between 2mb and 5mb. The second highest recorded carbon dioxide concentration of 5.7% by volume corresponded with the largest fall in pressure of 10mb, whereas the highest carbon dioxide concentration of 6.3% by volume corresponded with a fall in pressure of 8mb.

8.3 Ground Gas Risk Assessment

8.3.1 Gas screening values have been calculated for methane and carbon dioxide for individual boreholes on each of the six monitoring visits and these are presented on the gas summary tables in Appendix D.

8.3.2 With regard to methane concentrations and gas flows, the maximum calculated gas screening value is 0.0001 litres / hour based on a nominal methane concentration of 0.1% by volume (in the absence of any positive methane concentrations) and a nominal gas flow rate of 0.1 litres / hour (in the absence of any positive flow rates).

8.3.3 With regard to carbon dioxide concentrations and gas flows, the maximum calculated gas screening value is 0.0063 litres / hour based on the maximum recorded carbon dioxide concentration of 6.3% by volume and a nominal gas flow rate of 0.1 litres / hour (in the absence of any positive flow rates).

8.3.4 The worst case gas regime identified at the site is 0.0063 litres / hour carbon dioxide and this characterises the site as Characteristic Situation 1 under the Modified Wilson and Card method.

8.3.5 Based on the strict interpretation of CIRIA Report C665, where carbon dioxide concentrations exceed 5% by volume the guidance recommends that consideration be given to increasing the ground gas regime from Characteristic Situation 1 to Characteristic Situation 2. A Characteristic Situation 2 ground gas regime would therefore indicate that low level gas protection measures would be required in the proposed new visitor centre building at the site. However, the gas protection measures are only indicated to be required by virtue of the carbon dioxide concentration exceeding 5% by volume in one of the monitoring standpipes on four occasions (i.e. a maximum of 6.3% by volume in WS04), despite no flow rates being recorded within the same monitoring well on each monitoring visit.

8.3.6 The actual worst case gas screening value calculated to date for carbon dioxide (namely 0.0063 litres / hour) is well below the respective gas screening value for Modified Wilson and Card Characteristic Situation 1 (i.e. <0.07 litres / hour) where no gas protection measures would be required. This worst case gas screening value was recorded in WS04, where a 1m band of peat was encountered, which is anticipated as being the source of the marginally elevated carbon dioxide concentrations detected.

8.3.7 In consideration of the quantity and quality of gas monitoring data obtained; the fact that peat was only encountered in a thin (<1m) band and was fully saturated; and that the peat was not confined by a substantial thickness of the low permeability strata; it is considered that the site should be classified as Characteristic Situation 1. It is therefore considered that no gas protection measures would be required for the proposed new visitor centre building at the site even in the event that a piled foundation solution is employed.

8.3.8 According to the Envirocheck Report and the Building Research Establishment (BRE) Report BR211 entitled 'Radon: Guidance on protective measures for new buildings' dated 2015, radon protection measures are not required within new properties or extensions at this site.

9 Contamination Assessment

9.1 Revised Conceptual Site Model

9.1.1 Based on the findings of the Phase 2 intrusive investigation (which identified that Made Ground was present at the site) the conceptual site model has been revised indicating that the following contaminant linkages exist / do not exist, assuming the proposed development:

Source	Pathway	Receptor	Possible Contaminant Linkage	Significant Contaminant Linkage
Made Ground	Ingestion Dermal contact Inhalation (outdoor air)	Staff and visitors Construction Workers	No No	No No
Made Ground	Inhalation (indoor air)	Staff and visitors	No	No
Made Ground	Root uptake	Plants	No	No
Made Ground	Leaching	Groundwater – Secondary A Aquifer	No	No
Made Ground	Aggressive attack	Building materials and plastic water mains	No	No
Natural Alluvium	Ingestion Dermal contact Inhalation (outdoor air)	Staff and visitors Construction Workers	No* No	No* No
Natural Alluvium	Inhalation (indoor air)	Staff and visitors	No	No
Natural Alluvium	Root uptake	Plants	No	No
Natural Alluvium	Leaching	Groundwater – Secondary A Aquifer	No	No
Natural Alluvium	Aggressive attack	Building materials and plastic water mains	Unlikely	Unlikely
Contaminated groundwater	Ingestion Dermal contact Inhalation (outdoor air)	Construction workers	No	No
Contaminated groundwater	Inhalation (indoor air)	Staff and visitors Neighbouring occupants	No No	No No
Contaminated groundwater	Lateral and vertical migration	Groundwater – Secondary A Aquifer Surface water – Bottesford Beck	No No	No No
Contaminated groundwater	Aggressive attack	Building materials and plastic water mains	No	No

Source	Pathway	Receptor	Possible Contaminant Linkage	Significant Contaminant Linkage
Ground gases from Alluvium and Landfill (360m from site)	Generation, migration and accumulation inside properties	Staff and visitors Neighbouring occupants	No	No
	Exposure during earthworks	Construction workers	No	No

9.1.2 The term **significant contaminant linkage** as used above is defined as one that has been identified through risk assessment as representing unacceptable risks to human health or the environment. Where a significant contaminant linkage has been identified above remediation is considered necessary in order to break the pathway between the contamination source, migration pathway and the receptor.

9.1.3 The term **possible contaminant linkage** as used above is defined as one that has the potential to represent unacceptable risks to human health or the environment but has not been identified through risk assessment. Where a possible contaminant linkage has been identified above, further investigation and risk assessment may be required (as indicated by * above) to establish whether a significant contaminant linkage exists.

9.1.4 The updated Conceptual Site Model is also presented diagrammatically as the enclosed Drawing No. K-NC812.00_C405_1.

9.2 Soil Contamination

9.2.1 The findings of the investigation have not identified soil contamination within the Made Ground soils assessed from a human health and controlled waters protection perspective. In view of this, the Made Ground soils appear to be suitable for retention and re-use at the site. However, a sample of natural Alluvial clay analysed at the laboratory indicated potentially elevated concentrations of the PAHs benzo(a)pyrene and benzo(b)fluoranthene in relation to a public open space end use (i.e. public land near residential properties e.g. a grassed area outside residential housing).

9.2.2 Given that the natural Alluvial clay has been encountered at depths greater than 0.70m begl, together with the fact that these soils are situated beneath the Made Ground 'Topsoil' which is considered to be chemically suitable for the proposed end use, it is therefore considered that the notable PAH concentrations detected in the natural Alluvial clay are essentially encapsulated by the overlying Made Ground 'Topsoil'. Providing that the natural Alluvial clays (particularly around WS01) are not situated within 0.30m of the proposed finished ground level in soft landscaped areas upon completion of the development, it is considered that no remedial actions are necessary.

9.2.3 If the finished ground level is such that the natural clay is situated at a depth of less than 0.30m in soft landscaped areas, then further investigation / assessment to determine the significance of the PAHs detected in WS01 should be undertaken. In the absence of further investigation / assessment, appropriate remedial measures should be implemented, such as encapsulation by a clean soil cover layer.

9.3 Groundwater Contamination

9.3.1 The absence of elevated PAH concentrations in the groundwater sample from WS01 indicate that the notable PAH concentrations detected in the natural clay soil in WS01 are unlikely to pose a significant risk to controlled waters. Therefore no requirement to remediate soils and / or groundwater from a protection of controlled waters perspective has been identified at this stage. If further assurances are required in this regard, this report could be submitted to the Environment Agency in order gauge their opinion of the works undertaken.

9.4 Protection of the Proposed Buildings from Ground Gases

9.4.1 Based on the findings of the gas monitoring carried out at the site (i.e. six visits over three calendar months including monitoring undertaken during rapidly falling atmospheric pressure), it is recommended that the site is classified as Modified Wilson & Card Characteristic Situation 1. This assessment indicates that no gas protection measures would be required for the proposed development.

9.4.2 It is recommended that the findings of the ground gas assessment carried out are discussed with the Local Authority Contaminated Land Officer prior to any irrevocable actions on site.

9.4.3 It should also be noted that based on the findings of the desk study, including a review of the Landmark Envirocheck Report and the Building Research Establishment (BRE) Report BR211 dated 2015, no radon protection measures are required within the proposed new building at this site.

9.5 Unexpected Ground Conditions

9.5.1 During the proposed redevelopment of the site, should ground conditions differ significantly from those encountered during the course of the investigation, including the discovery of any odorous or visible contaminants or soils not encountered / assessed during this ground investigation, then works should be suspended until the suspect materials can be inspected and assessed by a suitably experienced Environmental Engineer / Scientist.

9.6 Health and Safety Precautions

9.6.1 Future occupiers of the completed development are considered to be at low risk from ground contaminants. However, during construction of the development, a high standard of health and safety awareness should be maintained in order to protect construction workers and the general public from exposure to any unknown contaminated soil and materials. Particular attention should be paid to the presence of PAHs in the natural soils (including around WS01). It is therefore recommended that the appropriate precautions given in Health and Safety Executive Report HS(G)66 ‘Protection of workers and the general public during the redevelopment of contaminated land’ are adopted.

9.7 Protection of Plastic Materials and Water Mains

9.7.1 Certain hydrocarbons (particularly aromatic compounds) can permeate plastic water pipes and taint drinking water supplies. Other hydrocarbons can cause aggressive attack to plastic building materials. No visual or olfactory evidence of hydrocarbons have been encountered on the site.

9.7.2 Given that water mains pipes are typically laid at depths of between 0.75m and 1.35m below ground level and that the PAH concentrations detected in the natural clay in WS01 are at 1.00m, the concentrations recorded have been compared to the guidelines published in the Water UK 'Contaminated Land Assessment Guidance' dated January 2014. As can be seen in the table below the PAH concentrations detected are below the thresholds for polyethylene pipe (PE):

PAH Equivalent Carbon No.	Units	Soil Concentration	PE Threshold
EC10-EC16	mg/kg	4.95	10
EC16-EC20	mg/kg	63.9	500

9.7.3 In view of the above, it is considered that standard PE water supply pipes are likely to be acceptable. Nevertheless it is recommended that clarification is obtained from the actual water supply utility company that the proposed type of water supply pipes are acceptable to them i.e. whether PE pipes or other materials such as Protecta-Line.

9.8 Waste Disposal and Environmental Permitting Issues

Waste Disposal

9.8.1 Any soils removed from the site must be disposed of at an appropriately permitted waste management facility. As producer of the waste, the employer has a Duty of Care to ensure that their waste is disposed of appropriately.

9.8.2 Where it is proposed to remove soils from site, it is recommended that the classification of the waste as inert, non-hazardous or hazardous is confirmed by discussion with the receiving waste management facility prior to disposal. In the case of inert and hazardous waste, this should identify whether further waste acceptance criteria (WAC) testing is required.

9.8.3 If the waste is classified as hazardous then the site should be registered with the Environment Agency as a hazardous waste producer. All waste types should only be transported by Environment Agency registered waste carriers.

9.8.4 There is a legal requirement to treat all waste (including contaminated soil) prior to disposal to landfill. Originating from the Landfill Directive, this legislation seeks to reduce the amount of waste going to landfills and reduce the impact of the waste when landfilled. Treatment is defined as "physical, thermal, chemical or biological processes, including sorting, that change the characteristics of waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery".

Reuse of Site Derived and Imported Materials

9.8.5 Should it be proposed to reuse site derived excavated soils (including natural materials) at the site or import naturally occurring unpolluted soils directly from another site, such activities may potentially fall under the Environmental Permitting (England and Wales) Regulations 2010. In 2011, Contaminated Land: Applications in Real Environments (CL:AIRE) published Version 2 of the Definition of Waste: Development Industry Code of Practice. The Code of Practice is supported by an Environment Agency Position Statement, which indicates:

"If materials are dealt with in accordance with the Code of Practice we consider that those materials are unlikely to be waste at the point when they are to be used for the purpose of land development."

9.8.6 Under the Code of Practice, such soils should not be a waste if they are retained on the site provided the re-use is "*certain*", the soils "*are suitable for use without any treatment*" and "*only the quantity necessary for the specified works*" as noted at the planning stage of the project is re-used. Rather than apply for a formal environmental permit or waste exemption, such works can be undertaken by self-regulation so long as the protocols in the Code of Practice are followed. The Code of Practice requires the preparation of a Materials Management Plan, which needs to be approved by an independent Qualified Person who provides a signed Declaration to the Environment Agency. Opus is able to assist in the preparation of the above documents and provide an appropriate Qualified Person to sign off the Materials Management Plan.

9.8.7 Should it be proposed to import made ground to site from an off-site source for use in construction, then either a waste exemption will need to be registered with the Environment Agency or a Standard Rules Permit obtained, depending on the quantities of waste to be imported. In the case of unpolluted naturally occurring topsoil and subsoil generated from other constructions sites, the Code of Practice can be adopted for the importation of these materials, omitting the requirement for a waste exemption or Standard Rules Permit.

9.8.8 Should it be proposed to import recycled aggregate to site, then so long as this has been processed in accordance with the WRAP protocols this is unlikely to be considered a waste and no waste exemption or Standard Rules Permit is required. If the imported recycled aggregate has not been processed in accordance with the WRAP protocols (or is not subject to a waste exemption or Standard Rules Permit), then uncertainty may arise as to whether this could be considered a waste and potentially at risk of regulatory action.

9.9 Uncertainty in the Phase 2 Contamination Assessment

9.9.1 The source of the Made Ground ‘Topsoil’, Made Ground ‘Clay’ and Made Ground ‘Concrete’ materials encountered on the site are uncertain. The most likely scenario is that the Made Ground materials are derived from reworked natural soils, into which anthropogenic material has become incorporated. No obvious evidence of contamination was observed in the Made Ground materials and the scope of the chemical analysis performed (heavy metals, PAHs and asbestos) in order to assess the quality of the soil and confirm suitability for use is considered reasonable.

9.9.2 Unexpectedly the PAH compounds benzo(b)fluoranthene and benzo(a)pyrene in the natural Alluvial clay were detected at concentrations that exceeded the published human health generic assessment criteria for public open space near residential land use. The laboratory were asked to retest the sample and a similar elevated result was recorded. The source of the elevated PAH concentration is uncertain given that the laboratory testing of the overlying Made Ground 'Topsoil' materials indicate that they are uncontaminated. In the absence of an obvious on-site or off-site source, the most probable explanation is that the elevated PAHs in the natural clay are attributed to a historic natural event such as a forest fire etc.

9.9.3 It should be noted that only one sample of the natural clay material has been analysed at the laboratory during the course of this investigation and it is unknown how widespread the presence of elevated PAHs is in these materials. For the purposes of the human health risk assessment it has therefore been assumed that all of the natural Alluvial clay contains similarly elevated levels of PAHs. However, the advancement of six window sample holes across the site provides a sufficient degree of confidence that the natural clay is located no closer to existing ground level than 0.70m. Similarly the chemical analysis of four samples of the overlying Made Ground 'Topsoil' provides a sufficient degree of confidence that the overlying soil quality is suitable for use. Given that there is considerable data to indicate that the natural Alluvial clay soil is suitably encapsulated, no requirement for further investigation / assessment has been identified at this time. In the unlikely event that the ground levels are being reduced to such an extent that the natural Alluvial clay soil is present within 0.30m of final ground level in soft landscaped areas then either further investigation / assessment and / or remediation should be undertaken.

10 Geotechnical Assessment

10.1 Ground Conditions Summary

10.1.1 The ground investigation encountered Made Ground ranging in thickness between 0.70m and 0.90m begl, over Alluvial clays and sands containing plant matter and peat.

10.1.2 The results of SPT testing indicate an increasing strength profile with depth of penetration, as indicated by the uncorrected 'N' values in the following table:

Depth (m)	Exploratory Hole					
	WS01	WS02	WS03	WS04	WS05	WS06
1.00	12	11*	7	10	13*	30*
2.00	5	6	6	1	4	3
3.00	6	28	14	4	1	14
3.60-4.00	>50 (3.80m)	>50 (4.00m)	>50 (4.00m)	>50 (3.90m)	>50 (3.60m)	>50 (3.80m)

KEY

- Alluvial Clay
- Alluvial Sand
- Alluvial Peat

Note: * indicates that the SPT was carried out partly in the Alluvial clay and partly in the Alluvial sand.

10.1.3 Derived N values within the natural strata generally ranged between 1 and in excess of 50 (virtual refusal) by depths of between 3.6m and 4.0m. The results indicate that the near surface clays and sands generally display a medium becoming low and very low strength / density profile at a depth of 2.0m begl and then increasing to dense / very dense. Although not definitively proven within the window sample boreholes, it is conjectured that the virtual refusal recorded at 3.6-4.0m may indicate the presence of the Scunthorpe Mudstone Formation beneath the Alluvium.

10.1.4 Groundwater was encountered in all of the exploratory holes on completion of drilling at depths varying between 1.47m and 1.88m begl. During the subsequent groundwater level monitoring, groundwater was observed in both of the monitoring standpipes on each of the six monitoring visits at depths ranging between 1.31m and 1.69m begl.

10.2 General Development Proposals

10.2.1 It is understood that North Lincolnshire Council propose to develop the site with a Visitor Centre which is proposed to occupy the northern central area of the site. It is understood that the visitor centre building is proposed to be single storey and it is assumed that this will comprise a modular construction.

10.3 Geotechnical Testing Results

10.3.1 Atterberg Limit analysis was undertaken on three soil samples of Alluvial clay. The results, summarised in the table below, indicate that the clay horizons within the Alluvium are of low volume change potential:

Stratum	Liquid Limit Range (%)	Plastic Limit Range (%)	Plasticity Index Range (Corrected) (%)	Natural Moisture Content (%)	Volume Change Potential
Alluvial Clay	33 – 40	16 – 20	14 – 20	20.0 – 21.4	Low

10.3.2 In total, pH and sulphate testing has been undertaken on 16 No. samples of the topsoil and the weathered Marlstone Rock Formation strata encountered. The results are summarised below:

Stratum	pH Value	Water Soluble Sulphate (mg/l)
Alluvial Clay	7.6	<10
Alluvial Sand	6.7	145
Alluvial Peat	7.3	220

10.4 Foundation Design

10.4.1 Foundation design options for the proposed development should be reviewed once the site levels, line loads and design details have been finalised.

10.4.2 The Made Ground and underlying soft, low strength clays, loose organic sands and peat are not considered to represent appropriate founding media for traditional shallow strip foundations and trench fill through to more competent strata is considered unlikely to be practical due to the anticipated depth of excavation and likely groundwater and stability problems.

10.4.3 Consideration could be given to the adoption of a reinforced raft foundation to support the anticipated lightly loaded single storey modular structure, spreading the load and therefore reducing the resultant consolidation settlements. This could involve removal of a suitable thickness of Made Ground and alluvial material and replacement with a blanket of thoroughly compacted Type 1 stone to an appropriate depth. However, the presence of variable thicknesses of 'peat' or 'peaty clay/sand' with peat proven to a depth of 2.8m may limit the feasibility of this option and the cost of removal and disposal of the existing Alluvium may prove prohibitive. Further assessment of this option should be completed based on defined line loads and acceptable settlement criteria.

10.4.4 Piled foundations are likely to represent a more practical and cost effective solution for the proposed development, transferring loads through the upper alluvial layers to the underlying Scunthorpe Mudstone Formation. It is recommended that the results of this investigation are submitted to suitably qualified and experienced piling contractors to formulate an appropriate pile design philosophy. It should be noted that piling contractors may require deeper boreholes to confirm the level and nature of the Scunthorpe Mudstone Formation to enable full clarification of the most appropriate design.

10.4.5 In accordance with EC7, all design values must be checked against the actual proposed factored foundation design loads, and a settlement calculation undertaken. At this stage, the foundation loadings are not known and hence such calculations cannot be carried out until this information is available.

10.5 Floor Slab Design

10.5.1 Given the varying depths of Made Ground from 0.70m to 0.90m begl and the variability of the alluvial soils across the site, together with the likely piled foundation solution, it is considered that a suspended ground floor slab design will be required for the proposed development.

10.6 Building Near Trees

10.6.1 A number of trees and hedgerows are present on the site and along the site boundary. Foundation designs should therefore be adjusted to take into account the potential influence of trees, either existing or proposed, on the design of foundations. For the raft foundation option, this issue would be resolved by the replacement of cohesive soils with a granular blanket. For piled foundations, the appointed contractor may need to incorporate an appropriate slip membrane in the upper sections of piles to accommodate potential clay volume change.

10.6.2 Assessment of potential tree influence should be completed based on the presence of clays of low volume change potential relative to a detailed tree survey and proposed planting schedule.

10.7 Construction

10.7.1 Anticipated excavation depths should generally be readily achieved using conventional plant (JCB 3CX or similar) within the Made Ground and natural soils.

10.7.2 Support must be provided for all excavations requiring entry by site workers in accordance with guidance presented in CIRIA Report 97 'Trenching Practice'. In addition, given the predominantly granular nature of the strata encountered, short and long term instability of excavations sides should be anticipated.

10.7.3 Given groundwater ingress was encountered between 1.47m and 1.88m begl in the exploratory holes, and a standing groundwater level of 1.31m begl has been recorded, groundwater in significant quantities may be encountered during construction at and below these depths. For relatively shallow excavations to depths of up to 1.3m, sumping and pumping is likely to prove adequate to deal with localised perched groundwater entries. For deeper excavations, if required, sheet piling, well pointing or a combination of both may be required to reduce water entries to within acceptable limits for construction purposes.

10.8 Concrete Specification

10.8.1 The ground conditions, pH values and water-soluble sulphate concentrations have been assessed for potential aggressive attack on concrete in accordance with BRE Special Digest 1 'Concrete in Aggressive Ground (2005)'.

10.8.2 The results for Made Ground and natural sands are within Design Sulphate Class DS-1. The results indicate an ACEC (Aggressive Chemical Environment for Concrete) Class of AC-1s.

10.8.3 The specific concrete mixes for the DS Class to be used at the site will be determined, mindful of the ACEC Class, by the site-specific concrete requirements in terms of the required durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any Additional Protection Measures (APM).

10.9 Soakaways/Drainage

10.9.1 A single falling head test was undertaken within each of the monitoring wells installed in WS01 and WS04, as reported under separate cover previously. The aim of this testing was to provide an initial indication of potential permeability of the sub-strata in order to assess whether it would be worthwhile carrying out formal soakaway testing in accordance with BRE DG365 for soakaway design purposes.

10.9.2 The results of the preliminary falling head tests indicated that there appears to be a certain amount of infiltration into the unsaturated strata at the site. However, the relatively shallow depth to groundwater (i.e. between 1.31m and 1.69m begl) may mean that the potential use of soakaways at the site may not be feasible, although this is subject to detailed design.

10.9.3 In view of the above, it is recommended that detailed soakaway testing in accordance with BRE Digest 365 should be carried out to enable detailed design for the proposed development.

11 Recommended Further Works

11.1 Based on the information obtained to date, it is recommended that the following further works are undertaken with a view to the proposed redevelopment of the site:

- Liaison with North Lincolnshire Council Contaminated Land Officer and the Environment Agency (if required) in order to obtain their comments and approval of the investigation and risk assessment works carried out to date, together with the proposed recommendations prior to any irrevocable actions on site;

- Should it be proposed to re-use excavated materials at the site, then preparation of a Materials Management Plan (signed by a Qualified Person), Verification Plan and Report in order to demonstrate compliance with the Environmental Permitting (England and Wales) Regulations 2007 may be necessary;

- Liaison with the water supply utility company to confirm that the proposed type of water supply pipes are acceptable to them i.e. whether PE pipes or other materials such as Protecta-Line.

- Liaison with a piling contractor for foundation design purposes.