Report No: C398/2
Date: September 2022 Rev A

GEOENVIRONMENTAL APPRAISAL
for land off
28 PADDOCK ROAD, STAINCROSS, BARNSLEY, SOUTH YORKSHIRE

Prepared for

Andrew Bailey Architects

Prepared by
G&M Consulting Ltd, The Chestnuts, Brackenhill Road, Haxey, Doncaster DN9 2LR

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PREPARED FOR:	Andrew Bailey Architects		
PREPARED BY:	G Swinbourne BSc. (Hons) MSc. DIC, FGS		
REVIEWED BY:	A Swinbourne BSc. (Hons) FGS, MIEnvSc ACIEH.		

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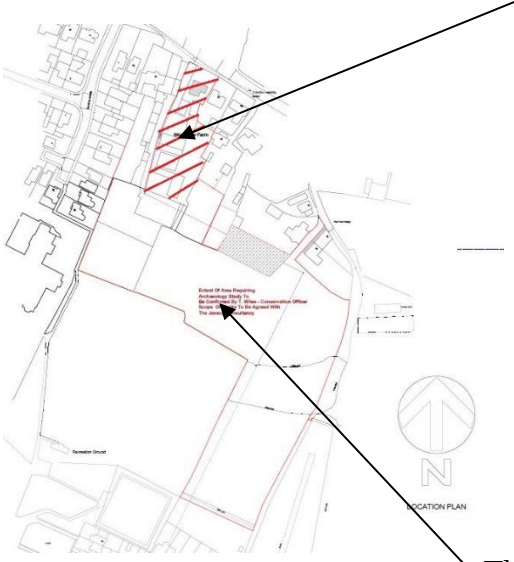
1.0 INTRODUCTION.

G&M Consulting Ltd (G&M) was commissioned by Andrew Bailey Architects (AA2L), to undertake a geoenvironmental appraisal of land off 28 Paddock Road, Staincross, Barnsley, Yorkshire. It is understood that a planning application is being submitted in support of the development of the site for residential purposes.

The proposed development layout is shown on Drawing No RMH-P02 Rev J, dated June 2022, prepared by AA2L, a copy of which is presented in Appendix A of this report.

The area under investigation is shown below,



The location of the site is shown on Drawing No C398/2/1, presented in Appendix A of this report.

1.1 Project Brief.

A number of phases of investigation, including intrusive work, have already been carried out on the site, by G&M, which are covered in the following reports;

- Preliminary Investigation of land at 28 Paddock Road, Staincross, Barnsley. Report Ref C398, dated February 2021.
- Soakaway Tests on land off 28 Paddock Road, Staincross, Barnsley. Report Ref C398/02/ATS, dated 15th November 2020.
- Land off Paddock Road, Staincross, Barnsley, South Yorkshire, Mining Investigation Report. Report Ref C398, dated March 2021.
- Geoenvironmental Appraisal of land off 28 Paddock Road, Staincross, Barnsley, South Yorkshire. Report Ref C398/1, dated April 2021 (Report submitted in discharge of conditions associated with PA (2017/1387)

Where appropriate, information and/or results from the above investigations pertinent to this geoenvironmental report have been incorporated.

Based on the results of the above reports, it was proposed by G&M to undertake a Phase 2 geoenvironmental intrusive site investigation of the area of development.

This report details the results of the intrusive investigation and makes recommendations with regards to the proposed development. This report should be read in conjunction with the preliminary investigation report, referenced above, which contains a description of the site, environmental setting and initial conceptual site model (CSM) from which the investigation rationale was derived.

Fieldwork, supplementary to that detailed in the reports above, was undertaken on 15th November 2021 and comprised the drilling of eight window sample boreholes with the installation of eight combined gas and groundwater monitoring wells. Following completion of the fieldwork selected soil samples were scheduled for a range of chemical and geotechnical laboratory tests. Ground gas monitoring of the wells was undertaken on six occasions over a nominal three month period.

The site as a whole (including the area of hatching shown above) is an irregular plot of land covering an area of approximately 2.3 hectares. It fronts to the north on to Paddock Road where it is only a narrow plot of land approximately 20 m wide and running south for approximately 90m before widening out into a larger L shape plot of land. One limb of the L is approximately 190 m by 70 m with the long axis aligned east west. The second limb is at the eastern end of the first and extends to the south, it is approximately 175 m by 55 m with the long axis aligned north south. The narrow stripe off Paddock Lane is occupied by a number of buildings associated with Woodview Farm. The remaining area of the site is open fields / scrub land.

The overall fall in ground level across the site from Paddock Road to the most southerly point is approximately 20 m and that from Paddock Road to the southern edge of the east west trending section of the site 12 m.

The site is bordered to the north by the gardens of residential properties that front on to Paddock Road or associated side roads, to the west and south by a mixture of open spaces and residential properties and to the east by fields and allotments.

1.2 Limitations.

This investigation report, which is designed to meet the requirements of all relevant current guidance, presents the factual information and interpretation of the data obtained during this appraisal and recommendations relevant to the defined objectives.

The comments and opinions presented in this report are based on the findings of a review of available information and ground conditions encountered during the intrusive investigation work. There may be other conditions prevailing on the site which have not been disclosed by this investigation and which have not been taken into account by this report. Responsibility cannot be accepted for conditions not revealed by the investigation. Any diagram or opinion of the possible configuration of ground conditions between exploratory holes is conjectural and given for guidance only and confirmation of intermediate ground conditions should be considered if deemed necessary.

During the course of the works G&M did not notice the presence of any Japanese Knotweed, or other such invasive plant species. However, it should be noted that G&M are not qualified ecologists and as such cannot guarantee the absence of knotweed or other invasive vegetation. If necessary the possible presence of such vegetation should be confirmed by a qualified ecologist if necessary.

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2.0 GROUND INVESTIGATION.

2.1 Design and Strategy

The Phase 1 preliminary investigation prepared previously, referenced above, was used as the basis for the design of an appropriate intrusive ground investigation. The preliminary investigation considered the site as a whole, includes the parcel of land immediately off Paddock Road, which is covered under BMBC planning approval 2017/1387. The main findings of the desk study as given in the summary to the report were as follows:

1. *Historical maps relating to the site indicate that the northern portion of the land has been occupied since 1850s by a collection of buildings. The building layout and number expanded throughout the sequence of maps. The buildings are inferred to be predominantly agricultural structures, with a residential house being constructed on the northernmost tip of the site facing on to Paddock Road sometime during the mid 20th century. The site was labelled 'Woodview Farm' on a number of map issues.* (Note the northern part of the site, referenced above does not form part of the site investigated as part of this work.)

2. *Examination of historical maps has revealed the presence of coal mining activity within close proximity to the site. 'North Gawber Colliery' was situated to the south of the site and maps depict significant earthworks on land surrounding the colliery, inferred to be accumulations of mine tailings. Mining activities may have given rise to some localised contamination, including the potential for ground gases to emanate from underlying strata.*

Historical maps reviewed as part of the preliminary investigation and observed during the walkover survey indicate the area under investigation has remained undeveloped since the earliest map dated 1850, and is likely to have been used on occasion for agricultural purposes

The aim and purpose of the ground investigation was to verify the nature and depth of any made ground and shallow subsoils across the site, determine the ground gas regime, to allow informed decisions on potential remediation options that might be required in order to break the direct contact exposure pathways that were identified at the Phase 1 stage.

Exploratory Hole Type	Purpose
Window Sample Boreholes and Machine Excavated Trial Pits	To determine the general nature of shallow soils underlying the site, including the; ◦ Nature, distribution and thickness of any potential made ground. ◦ Nature, degree and extent of ground contamination. ◦ Determination of the presence of shallow underlying natural ground ◦ Install combined gas and groundwater monitoring installations. ◦ To help identify and inform suitable remedial options

The scope of the intrusive investigation is detailed below;

2.2 Scope of Works.

Fieldwork on the subject site was undertaken on the 4th and 5th November 2020 (worked carried out as part of the soakway testing), 15th February 2021 (work carried out as part of the mining investigation) and 15th November 2021, and comprised;

- Drilling of eight window sample boreholes, referenced WS1 to WS8 inclusive, to depths of between 1.20 m to 3.45 m below ground level (bgl), with the installation of eight combined gas and groundwater monitoring installations.
- Excavation of fifteen trial pits, referenced TP3 to TP17, to depths of between 1.40 m and 2.10 m bgl, excavated as part of a separate report investigating historic mining and soakaway testing on the site.
- Drilling of eight rotary open holes, referenced BH1 to BH8, to depths of between 20.0 m and 30.0 m, drilled as part of a separate report investing historic mining.
- Excavation of two trial scrapes, referenced TT01 and TT02, undertaken as part of the historic mining investigation.

The investigation was scoped using guidance presented in BS 10175:2011+A2:2017, CIRIA C665:2007, the principals of Land Contamination Risk Management (LCRM) - Environment Agency October 2020 and BS EN 1997:2004 and 2007.

The exploratory hole positions were set out and the fieldwork supervised by a G&M engineering geologist. The locations of the holes are shown on Drawing No C398/2/2, presented in Appendix A of this report.

The window sampling was carried out using a Dando Terrier tracked drilling rig. This uses a drop weight to drive steel sampling tubes with a plastic liner. The diameter of the hole reduces with depth to reduce friction on driving the sampling tubes.

The mechanically excavated trial pits and trial scrapes were undertaken using a 6-tonne tracked excavator.

The pits were backfilled with arisings, compacted using the bucket, in the approximate order in which they were excavated.

The combined gas and groundwater monitoring installations comprised 50 mm diameter HDPE pipe, consisting of a lower slotted section of casing surrounded by single size non-calcareous gravel. The upper section of the well was constructed from plain casing sealed with a bentonite/cement seal. A flush metal lockable security cover was concreted into place to complete the well installation at the ground surface.

Details of the installations are shown below;

Exploratory Hole No	Drilled Depth (m bgl)	Depth of Monitoring Well (m bgl)
WS1	3.45	3.10
WS2	1.20	1.20
WS3	1.45	1.45
WS4	2.45	2.45
WS5	2.70	2.50
WS6	2.45	2.25
WS7	1.45	1.45
WS8	2.55	2.55

A full set of photographs taken of selected trial pits dug during the fieldwork is presented in Appendix E of this report.

2.3 Strata Description.

Depths and descriptions of strata encountered together with details of the samples recovered are presented on the exploratory hole record sheets presented in Appendix B of this report. Procedures and principles contained in BS EN ISO 14688-1 (2002), as amplified by BS 5930 (2015) were followed.

The depths of strata on the record sheets are recorded from current ground levels at each location.

2.4 Sampling

Small disturbed samples of soil for chemical analysis, were also taken and placed in amber glass jars as appropriate. Between the exploratory hole positions, equipment was thoroughly cleaned and dried.

In accordance with best practice (BS10175:2011) samples for chemical analysis were collected in appropriate containers, kept in a chilled cool box whilst on site, retained in a fridge (below 2^{o}C) until the day of collection, packed in a chilled cool box on the day of collection and transported in this to the laboratory.

2.5 Laboratory Testing

Schedules for contamination and geotechnical testing were drawn up by G&M.

Selected soil samples were tested for a range of potential contaminants, under a sub-contract with i2 Analytical Ltd (i2), a UKAS/MCERTS accredited laboratory. The analytes tested are listed in Section 4.2 of this report. The results of soil analysis, as received from the laboratory, are presented in Appendix C of this report.

3.0 GROUND CONDITIONS AND MATERIAL PROPERTIES

A complete record of all the strata encountered is given on the attached exploratory hole logs. In general, these show a localised topsoil or made ground over what is presumed to be weathered coal measures strata, underlain by bedrock

3.1 Topsoil/Made Ground

Topsoil was encountered in TP3, TP4 and WS8 to a thickness of 350mm and described as a very sandy clay.

Localised made ground was only encountered in trial pit TP13 to a depth of 1.20 m. This material was described as a very clayey gravelly fine to coarse sand with a low cobble content. The gravel content comprises a mixture of fragments of brick, mudstone and coal. The cobbles comprised concrete and sandstone.

3.2 Weathered Coal Measures Deposits

The remainder of the trial pits and boreholes encountered a cohesive subsoil from surface, which also underlaid the made ground and topsoil described above. This soil comprised a generally firm and stiff, locally very stiff gravelly clay, to depths (where fully proven) of between 0.45 m and 1.7 m bgl. The gravel component was recorded as subangular fine to coarse mudstone lithorelicts and locally coal.

In TP7, WS5 and WS6 the full depth of this cohesive soil was not proved, to the base of the exploratory holes at 2.10 m, 2.7 m and 2.45 m bgl, respectively. In TP7, a coal was recorded between 1.35 m and 2.0 m bgl, and was described as a very weak to weak black vitreous extremely closely fractured coal.

With the exception of TP7, WS5 and WS6, bedrock was encountered in all of the exploratory holes beneath the cohesive subsoils. In TP4, TP8, TP9, WS3 this comprised a thinly laminated to very thinly bedded sandstone. In TP3, TP5, TP6, TP10, TP11, TP12, TP13, WS1 to WS5 and WS7 and WS8 this comprised a stiff to extremely weak thinly to thickly laminated mudstone (where bedding was observed in the trial pits). In all of the trial pits and boreholes, the mudstone and sandstone were recovered to surface as gravel and cobbles.

3.3 Groundwater

During the excavation work a seepage of groundwater was recorded in trial pit TP4 at 1.35 m bgl.

No ground water was encountered during drilling of the boreholes site works however monitoring visits carried since completion of site works have recorded ground water, the table below summaries the standing groundwater levels recorded within the monitoring wells installed by G&M. Six monitoring visits were made to site, post fieldwork.

Exploratory Hole No	Drilled Depth (m bgl)	Depth of Monitoring Well (m bgl)	Groundwater Level – Depth Range During Monitoring Period (m bgl)
WS1	3.45	3.10	0.95 - 1.25
WS2	1.20	1.20	0.64 – 0.92
WS3	1.45	1.45	Dry – 1.37
WS4	2.45	2.45	0.46 – 0.65
WS5	2.70	2.50	Dry
WS6	2.45	2.25	1.42 – 2.08
WS7	1.45	1.45	0.27 – 0.44
WS8	2.55	2.55	Dry

It should be borne in mind that water levels are likely to fluctuate with season/rainfall and may therefore be substantially higher at wetter times of year than those found during this investigation.

3.4 Visual / Olfactory Evidence of Contamination

The made ground encountered in TP13 was found to include varying proportions of brick, coal, concrete, mudstone and sandstone which can produce elevated concentrations of certain contaminants, such as toxic and phytotoxic metals, sulphate and PAH.

3.5 Ground Gas and Vapours

Ground gas monitoring has been carried out on six occasions over a three month period, and the results are summarised below. Full details of the ground gas monitoring are included in Appendix D of this report

Well	Methane (range) % v/v	Carbon Dioxide (range) %v/v*	Oxygen (range) %v/v*	VOC (ppm)	Flow (range) l/hr*
WS1	ND	0.8-1.3	12.7-17.2	0	0
WS2	ND	1.2-2.4	2.6-15.0	0.4	0 - 0.7
WS3	ND	2.6-4.0	0.0-15.8	0.2	0
WS4	ND	0.3-0.7	15.2-19.1	0.3	0
WS5	ND	5.0-7.1	2.9-13.8	0.6	0
WS6	ND	0.3-0.7	15.0-16.5	0.2	0

WS7	ND	0.2-0.7	20.1-20.9	0.2	0 – 0.1
WS8	ND	4.4-7.1	5.3-13.8	0	-0.1 - 0.2

ND - Not Detected. NR - * peak reading

Barometric air pressure for the visits was between 996 mb and 1022 mb.

4.0 RESULTS OF CHEMICAL TESTING

4.1 General

For this site, measured values were compared to Generic Assessment Criteria (GAC) derived for a residential with plant up take end use.

Chemical analysis was undertaken on representative soil samples recovered from across the site. The determinands were selected to provide information on the distribution of potential contaminants. The general analytical suite was supplemented with additional analysis where former land usage, as determined from the desk study, or visual or olfactory observations suggested the presence of additional contaminants.

The majority of initial screening levels (GAC's) used in the production of this assessment have been taken from the guidelines introduced by:

- DEFRA C4SL's, DEFRA 2015.
- Joint Land Quality Management Ltd (LQM) and Chartered Institute of Environmental Health (CIEH), Generic Assessment Criteria for Human Health Risk Assessment, S4UL's, Land Quality Press 2015.

Usually statistical testing is undertaken for the Planning Scenario by the methods described in CL:AIRE "Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration", September 2020. This statistical testing is undertaken to determine whether there was sufficient evidence that the true mean concentration of each determinand was less than the relevant critical concentration for that component. However, given the fact that a proportion of the sampling was carried out on a targeted basis, detailed statistical assessment of the data has not been conducted, instead individual contaminant concentrations have been compared to their relevant assessment criteria.

4.2 Testing Schedule

Following completion of the fieldwork samples were selected for testing as follows;

Laboratory Analysis	**Investigation Date**			
	15/02/21		**15/11/21**	
	Made Ground	**Natural Soils**	**Made Ground**	**Natural Soils**
Total concentrations of arsenic, cadmium, chromium (incl hexavalent), copper, lead, nickel, selenium, zinc, mercury	1	7	-	8
Water soluble sulphate, pH	1	4	-	4
Phenol	1	7	-	8
Speciated PAH	1	7	-	6

Laboratory Analysis	Investigation Date			
	15/02/21		15/11/21	
	Made Ground	Natural Soils	Made Ground	Natural Soils
GCMS Pesticide Screen	-	-	-	4
SVOC's (Herbicide/pesticide screen)	-	3	-	-
Asbestos	-	-	-	3

4.3 Soil Analysis

The chemical analysis results and screening criteria are summarised below. The results for the made ground and natural soils have been combined for an initial assessment.

Summary of Total Soil Concentrations

Determinand	GAC (1% SOM) (mg/kg, unless otherwise stated)	No. of samples above screening value	No. of samples tested	Maximum concentration above GAC (mg/kg, unless otherwise stated)
Metals/Metalloids				
Arsenic	37 [2]	0	16	
Cadmium	11[1]	0	16	
Chromium (VI)	21 [2]	0	16	
Lead	200 [2]	0	16	
Mercury	40 [1]	0	16	
Selenium	250 [1]	0	16	
Copper	2400 [1]	0	16	
Nickel	180 [1]	0	16	
Zinc	3700 [1]	0	16	
Inorganics				
pH	<5	0	9	
Water Soluble Sulphate	0.5 g/l [3]	0	9	
Organics				
PAHs				
Acenaphthene	210[1]	0	14	
Anthracene	2400[1]	0	14	
Acenaphthylene	170[1]	0	14	
Benzo(a)anthracene	7.2[1	0	14	
Benzo(b)fluoranthene	2.6[1]	0	14	
Benzo(k)fluoranthene	77[1]	0	14	
Benzo(g,h,i)perylene	320[1]	0	14	
Benzo(a)pyrene	5.0[2]	0	14	
Chrysene	15[1]	0	14	
Dibenz(a,h)anthracene	0.24[1]	0	14	
Fluoranthene	280[1]	0	14	
Fluorene	170[1]	0	14	
Indeno(1,2,3-cd)pyrene	27[1]	0	14	
Naphthalene	2.3[1]	0	14	
Pyrene	620[1]	0	14	
Phenanthrene	95[1]	0	14	
Others				
Monohydric Phenol	120[1]	0	16	
Herbicide/Pesticide Screen	Present	0	7	
Asbestos	Fibres present	0	3	

[1] LQM/CIEH (2015) Generic Assessment Criteria for Human Health Risk Assessment. 2nd Ed. (for a sandy soil with 1% SOM and pH 7.0)
[2] DEFRA C4SL's, DEFRA 2015
[3] BRE (2005) Special Digest 1, 3rd Edition, Concrete in aggressive ground. Upper limits for DS-1 Design Sulphate Class concrete.

The sample of made ground (TP13-0.1m) did not record any concentrations in excess of the relevant screening values detailed above.

None of the samples tested from the natural sub-soils recorded concentrations in excess of the relevant screening values detailed above.

As a precautionary measure, and considering the previous agricultural use of the site, a herbicide/pesticide screen was carried out on seven samples of the natural soils. No compounds were recorded in any sample.

5.0 QUALITATIVE RISK ASSESSMENT AND REVISED CONCEPTUAL MODEL

The preliminary conceptual site model, developed from the preliminary investigation information, as presented in the G&M report, has been revised in light of the ground investigation and chemical analysis results presented above. The revised conceptual model has been developed for the proposed future land use (Residential). This summarises the understanding of surface and sub-surface features, the potential contaminant sources, transport pathways and receptors

Human Health – further considerations:

- Elevated hazardous ground gas.

Summary of Identified Pollutant Linkages
In summary the revised conceptual site model has identified the following potential pollutant which could result in an unacceptable risk to the proposed end-use, denoted as a moderate or higher potential of significant pollutant linkage on the conceptual site model.

Source	Risk	Potential Contaminants	Exposure Pathway	Primary Receptor/s	Complete Pollutant Linkage
Made Ground - on site	Moderate	Inorganic contaminants	Skin contact Ingestion	Construction workers, built development, End users of site,	Yes: Although no elevated levels of contaminants were recorded during the investigation, a small area of made ground was encountered around TP13. Residential properties are likely to have gardens and areas of soft landscaping, clean capping of gardens and areas of soft landscaping will be required in the area of made ground encountered in TP13. Further investigation of this area should be undertaken, and detailed within a Remediation Strategy.
Made Ground - on site	High	Ground gas	Migration (lateral and vertical) Inhalation, explosion		Yes: Elevated levels of CO2 encountered within the monitoring wells. Basic Radon protective measures are required for the site.

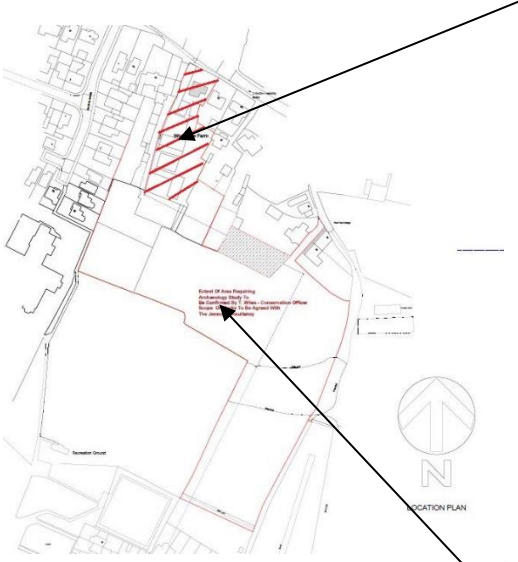
6.0 CONCLUSIONS AND RECOMMENDATIONS.

6.1 General.

G&M Consulting Ltd (G&M) was commissioned by Andrew Bailey Architects, to undertake a geoenvironmental appraisal of land off 28 Paddock Road, Staincross, Barnsley, Yorkshire. It is understood that a planning application is being submitted in support of the development of the site for residential purposes.

The proposed development layout is shown on Drawing No RMH-P02 Rev J, dated June 2022, prepared by AA2L, a copy of which is presented in Appendix A of this report.

The area under investigation is shown below,



The location of the site is shown on Drawing No C398/2/1, presented in Appendix A of this report.

Historical maps reviewed as part of the Phase 1 preliminary investigation and observed during the walkover survey indicate the area under investigation has remained undeveloped since the earliest map dated 1850, and is likely to have been used on occasion for agricultural purposes

It has been assumed that ground levels will not change significantly from those described in this report, or that the proposed end use of the site will not change from that detailed above. If this is not the case, then amendments to the interpretation and conclusions in this report may be required.

6.2 Contamination Constraints to Development

Risk Evaluation for Proposed Land Use

No elevated concentrations of contaminants were recorded as part of the investigation. It is therefore considered that the existing subsoils present on site do not pose a risk to human health.

It is possible that areas of unidentified contamination or made ground may be encountered during the development works. If any visible fragments of asbestos, areas of noxious, odorous, fibrous or liquid etc.

contamination are encountered, then works should stop immediately and further advice sought from a suitably experienced and qualified consultant. It is recommended that a watching brief be maintained during the development work for this purpose.

Future site users
The development proposals indicate the future end use of the site to be residential with areas of private gardens and soft landscaping. This is considered to represent a high sensitivity end use.

Based on the source>pathway>receptor philosophy and the chemical results obtained as part of this investigation, it is considered that the subsoils present on site pose a negligible risk to end users through ingestion, dermal contact or inhalation and that no remedial action will be required to break this linkage.

The area of localised made ground encountered around TP13 should be investigated further and the full extent of this material delineated and further tested. It is likely that this localised made ground because of its unsuitability as a growing medium, if left on site in areas of private gardens or soft landscaping, there will be a need to cap with clean cover soils. This is to provide a healthy medium for plant growth and to remove any remaining pathways for exposure of end users to residual contaminants. It is recommended that a minimum of 600mm of clean capping soils (including 150mm of topsoil) are placed in this localised area. This thickness is subject to regulatory approval.

Controlled Waters Receptors
Considering the fact that the results of the chemical testing and that the site is predominantly underlain by cohesive subsoils, that would limit any lateral or vertical migration of mobile contaminants, and that the localised made ground soils will be either removed or capped with hard stand or clean capping soils (thereby effectively eliminating surface water infiltration and leachate generation), it is considered that the soils are considered to pose a negligible/low risk to controlled waters and that no further remediation is considered necessary. This opinion is subject to regulatory approval.

Construction and Maintenance Workers
Based on the current information it is considered unpikely that the soils present on site pose a short term (acute) risk to groundworkers. It is however recommended that good health and safety procedures should be adopted by ground workers, including no eating or smoking on site, designated clean and wash areas and protective clothing, e.g. overalls, gloves etc. Good working and soil management practices to prevent the generation of dust, should also be implemented.

Any potential risks must be specifically assessed as part of the health and safety evaluation for the works to be performed in accordance with prevailing legislation. Site practices must conform to the specific legislation requirements and follow appropriate guidance (e.g. HSE, 1991; CIRIA 1996).

Adjacent site users
Provided good ‘housekeeping’ practices are observed during the ground works, health and safety compliance is achieved, and wastes are appropriately handled, stored and disposed, then it is considered that there is a negligible/low short term risk to adjacent site users during the works.

Utilities
The results of the chemical testing and details of the proposed enabling works should be provided to the appropriate utility companies to determine the necessity for service protection

Built Development
This assessment of the potential for chemical attack on buried concrete is based on current guidance contained in BRE Special Digest 1 ('SD1', 2005) Concrete in Aggressive Ground Part 1: Assessing the aggressive chemical environment. Third Edition.

Soil pH values recorded in eight samples of made ground range from 5.7 to 7.8 with corresponding water-soluble sulphate (SO_4) results in the range 0.0096 g/l to 0.25 g/l. From these results a 'Characteristic Value' of 5.7 is derived for pH and 0.25 g/l for water soluble sulphate.

A single result from the made ground in TP13 recorded a pH of 8.3 and a SO_4 result of 0.029 g/l.

Based on the results, using Table C2 (SD1) for brown field sites the results for the water soluble sulphate indicate a Design Sulphate Class for the site of DS-1, with an ACEC class of AC-1s for static groundwater conditions and AC-1 assuming mobile ground water conditions.

6.3 Ground Gas

Gas monitoring has been undertaken on six occasions over a nominal three month period.

Guidance on the assessment of ground gas is given in CIRIA C665 (2007) *'Assessing Risks Posed by Hazardous Ground Gases to Buildings'* and BS8485:2015+A1:2019 *'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'*.

The gas monitoring carried out to date has recorded no methane and a peak carbon dioxide concentration of 7.1%, with a maximum gas flow of 0.7l/hr. A worst case gas screening value (GSV) of 0.0497 l/hr has been calculated for carbon dioxide.

Based on the above GSV, the ground gas regime for the proposed structure would initially be assessed as Characteristic Situation CS1, based on Table 8.5 and 8.6 of CIRIA C665. However, as the carbon dioxide concentrations recorded in WS5 and WS8 are above 5%, then in accordance with the above standards the CS value is increased by one band to CS2 (Refer to Table 8.5, CIRIA C665). CS2 would require basic gas protection measures to be installed in the building. Guidance on the appropriate gas protection measures are given in BS8485:2015+A1:2019. The measures used are generally a combination of a ventilation layer, floor slab or raft foundation and gas roof membrane, the options used would depend to some extent on the foundation construction adopted.

According to the desk study basic radon protection measures are required for the protection of the proposed buildings at this location.

6.4 Regulatory Approval

The conclusions and recommendations presented above are considered practical based on the findings of this investigation. The conclusions and recommendations cannot, however, be guaranteed to gain regulatory approval, and therefore this report should be submitted to the regulators for their comment/approval as part of any planning approval.

The above recommendations comprise a general outline of possible or likely works. A remediation strategy report should be produced and agreed with the regulatory authorities prior to development.