Contaminated Land
Air Quality
Environmental Audit

SMITH GRANT Environmental Consultancy LLP

Partnership No: OC 300776

LAND FRONTING WELL STREET, BUCKLEY

PHASE I & II CONTAMINATED LAND & GEOTECHNICAL ASSESSMENT

For: Flintshire County Council

September 2017

R2458-R01-v1

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LAND FRONTING WELL STREET, BUCKLEY

PHASE I & II CONTAMINATED LAND AND GEOTECHNICAL ASSESSMENT

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EXECUTIVE SUMMARY

Current Site Status	The site currently comprises a vacant parcel of open land occupied by two fields separated by a hedgerow
Proposed Site Use	Residential, anticipated to be low rise residential development with private gardens and supporting infrastructure
Scope of Works	SGP has undertaken a Stage 1 and 2 Geo-Environmental Investigation of the site to assess the suitability of the site for the future development and to determine further investigation and remedial requirements, if necessary. Works comprised the following: • desk study and background information review; • machine excavation of 12 trial pits; • laboratory chemical analysis of representative shallow soil samples for a range of standard contaminants of concern; • geotechnical laboratory testing;
Site History	The historical mapping indicates the site to have been remained undeveloped throughout its mapped history (1871-1878 to present day).
Site Setting	The site is situated within the town of Buckley with residential and commercial agricultural premises surrounding. The site topography is shown on Ordnance Survey mapping to slope from the north to the south at approximately 160m to 150m AOD.
Ground Conditions	Ground conditions across the site are typically uniform, comprising of a surface covering of topsoil overlying firm to stiff glacial clay. At one location in the south of the site, on the southeast boundary, soft clay with peat was encountered, however this probably represents a minor portion of the site although the area has not been fully delineated.
Groundwater Conditions	Groundwater was not encountered in the majority of entries, although the trial pit in the southeast flooded.
Contamination Assessment	Concentrations of most determinants were below the respective assessment criteria based on a residential land use scenario with exception of exceedances of lead. Some of these exceedances were marginal, however a majority of topsoil samples were impacted, and unless further assessment can demonstrate risks to future residents are not unacceptable, it must be assumed that the topsoil on the site will not be suitable for private gardens (although it may be suitable for other uses). Characterisation of the ground gas regime based on ground conditions indicates no requirement for gas monitoring or dedicated gas protection measures to manage risks from methane or carbon dioxide, there is a requirement for radon protection measures to be installed within new dwellings which will provide a precautionary level of protection.
Foundations and Infrastructure	The strata sequence observed during the ground investigation is deemed to be suitable for a shallow, traditional spread foundations, except for the area of soft clay/peat where alternatives may need to be considered depending on the depth of the deposit. Stability and water ingress problems if excavations deeper than 1m are required in this area may occur and the material is also problematic for construction of

	pavements. Depending on the depth and lateral extent of the deposit, removal and replacement with engineered fill may be considered.
Conclusions and Recommendations	The presence of low to moderate levels of lead in topsoil should be confirmed, alternatively mitigation through the application of a simple clean soil cover system would also be readily achieved. Works to determine the thickness and extent of the area of soft ground in the south of the site and determine whether its removal to improve the geotechnical properties of the impacted area is required should be undertaken. However, the investigation has not indicated any major constraints to redevelopment of the site and further investigation is only required to allow detailed design of an appropriate Remediation Strategy and develop an appropriate foundation schedule once development proposals are available.

1. Introduction

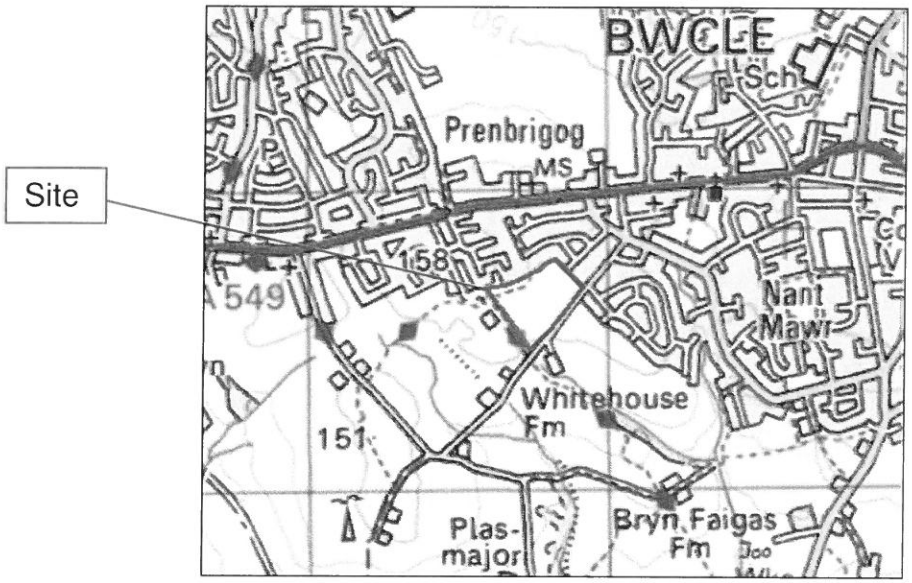
1.1. Flintshire County Council (FCC) instructed Smith Grant LLP (SGP) to undertake a Stage 1 & 2 Contaminated Land and Geotechnical Assessment on a parcel of land fronting Well Street, Buckley, Flintshire. SGP understand that the assessment is required to provide further information with regard to the potential for future residential development of the site.

1.2. Site details are:

Table 1.1: Site Details

Address	Land fronting Well Street, Buckley, Flintshire, CH7 2PQ.
National Grid Reference	326768 363646
Local Authority	Flintshire County Council
Site Area	~5.2 ha
Current Use of Site	The site comprises two open fields used for arable farming
Proposed Use	Potential future residential development

Figure 1.1: Site Location



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1.3. This report describes the Stage 1 (desk study and site inspection) and Stage 2 (intrusive investigation) work undertaken by SGP in accordance with the site investigation requirements. The assessment methodology for ground contamination assessment follows the framework in the EA / DEFRA Contaminated Land Report 11: 'Model Procedures for the Management of Land Contamination' 2004 and working to BS5930:2015.

1.4. The study comprises a review of readily available information on the environmental setting of the site and the site's previous and current uses with respect to potential risks to the environment or human health. An intrusive investigation was carried out which included trial-pit entries to a maximum depth of 3m bgl and the collection of representative soil samples for geotechnical and chemical testing. This report contains a qualitative and quantitative risk assessment, preliminary geotechnical assessment and, where appropriate, makes recommendations for further intrusive investigations and remedial actions appropriate to the future use of the site.

2. Information Sources

2.1. The principle sources of information consulted in the preparation of this report include:

Table 2.1: Information Sources

Date and reference	Author and source	Purpose and information content
Topography, geology, hydrogeology and hydrology		
http://mapapps.bgs.ac.uk [Accessed August 2017]	British Geological Survey.	distribution of geological units at surface including drift and artificial deposits, faults and mineral outcrops
https://www.ordnancesurvey.co.uk/osmaps/ [Accessed August 2017]	Ordnance Survey (OS), Explorer Map, 1: 10,000	general mapping information including structures, boundaries, ground features, water features etc.
http://www.ukradon.org [Accessed August 2017]	Public Health England	mapping defining radon affected areas in England & Wales
BRE 211	Radon: Guidance on Protective Measures for New Buildings, 2007	mapping identifying required radon protective measures in England and Wales
1720 August 2017	NKC Geotech Ltd.	Coal Mining Risk Assessment
Historical data		
Satellite imagery	Various	recent historical features (≥2001)
134175796_1_1, Purchased July 2017	Envirocheck: Landmark Information Group	historical mapping at 1:2,500, 1:10,000, and 1:10,560 from 1871 onwards.
Information review		
www.naturalresources.wales [Accessed August 2017]	Natural Resources Wales / Environment Agency	general information on flood risk zones; risks of flooding from rivers and sea, reservoirs and surface water.
www.magic.gov.uk [Accessed August 2017]	DEFRA	web-based interactive map containing information on nature conservation areas
134175796_1_1, Purchased July 2017	Landmark Information Group: Envirocheck Report	Hydrogeological, waste, geological, industrial, hazardous substances and sensitive land use information
134175796_2 Purchased July 2017	The Coal Authority: Non-Residential Mining Report (CON29M)	information regarding the risks associated with past, present and future mine workings.

2.2. Previous Investigations

2.2.1. SGP is unaware of any previous investigations having been undertaken at the site, however BGS records show 16 entries (possible boreholes or trial-pits) arranged in a systematic grid across the site, although information pertaining to their findings is marked as confidential. BGS labels the entries as 'St Julies RC School, Woolton, Liverpool'; whilst the labelling name suggests an error, the pattern of entries within the site boundary would suggest there has been a previous investigation, however, any such information has not been made available to SGP.

2.3. Site Inspection

2.3.1. A site inspection was undertaken by D Wayland, Senior Consultant on 02nd August 2017. Photographs were taken of salient features and are provided in Appendix A.

3. Development History and Current Status

3.1. Historical Development

3.1.1. A summary of significant features, developments and land uses shown on historical Ordnance Survey maps is provided in Table 3.1 below. Copies of selected maps are provided in Drawings D02-D07.

Table 3.1: Summary of Development History

Map	Site	Surrounds (all distances are approximate)
1871-78, 1:10,560 *(Low resolution mapping)*	The site comprises two large open fields separated by a dividing boundary (possible hedgerow) that crosses the centre of the site. No buildings, structures or features are indicated with the exception of a footpath situated along the northern boundary in the western part of the site, changing direction to the southeast along the dividing boundary line.	The site is surrounded by open fields. Buildings associated with 'Bistre Cottage Farm' are mapped 50m to the southeast of the site; residential properties are also located 50m to the west, 80m to the west and 120m to the northeast. Residential development has occurred in the wider surrounds, predominantly to the north / northeast of the site. Numerous coal shafts are present to the east / northeast of the site, the nearest of which is 400m from the site boundary. 'South Buckley Colliery' is mapped 670m to the northeast. Two wells are indicated in the vicinity of the site, 140m to the north and 160m to the southeast.
1872-84 1:2,500 See drawing D02	No significant changes to site.	Ponds are present 30m to the south and 50m west of the site.
1881, 1:10,560 *(Low resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1899, 1:2,500 See drawing D03	No significant changes to site.	Limited residential development has occurred to the northwest, north and northeast, the nearest of which is 120m from the site boundary. Amongst the recent residential development, a 'Smithy' is present 230m to the northeast. Reservoirs ('Hawarden & District Water Works') have been constructed 210m to the north of the site.
1900, 1:10,560 *(Low resolution mapping)*	No significant changes to site.	The coal shafts to the east / northeast of the site are either no longer mapped or are annotated 'Old Shaft(s)'. The former 'South Buckley Colliery' in now labelled 'South Buckley Brick Works'.

1912, 1:2,500 See drawing D04	No significant changes to site.	A building has been constructed 20m to the west of the site (probably a residential / farm building).
1914, 1:10,560 *(Low resolution mapping)*	No significant changes to site.	A surface water course (likely a drainage ditch) is shown appearing to originate from 'Bistre Cottage Farm' 30m to the southeast flowing in a south-easterly direction.
1938, 1:10,560 *(Low resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1954, 1:10,560 *(Poor resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1961, 1:2,500 See drawing D05	No significant changes to site.	The pond 50m to the west of the site appears to have been infilled. Residential development has occurred at distances of 160m and beyond to the northwest, north and east of the site.
1963-64, 1:10,000 *(Low resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1968, 1:10,000 *(Low resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1970-75, 1:2,500	No significant changes to site.	Significant residential development has occurred to the northwest, north and east of the site with properties directly adjacent to the northeast boundary. An electrical substation has been built 70m to the northeast and a tank is mapped 90m to the north. The reservoirs to the north are now mapped as being 'covered'.
1973-74, 1:2,500	No significant changes to site.	Further residential development has occurred directly to the north / northwest of the site and beyond.
1970-75, 1:10,000 *(Low resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1970-75, 1:2,500	No significant changes to site.	Residential development has occurred to the north of the site.

1977-82, 1:2,500 See drawing D06	No significant changes to site.	Residential development has occurred directly to the north of the site.
1982-87, 1:2,500	No significant changes to site.	Residential development has occurred to the west of the site.
1979-89, 1:2,500	No significant changes to site.	No significant changes to surrounds.
1991-92, 1:10,000 *(Low resolution mapping)*	No significant changes to site.	No significant changes to surrounds.
1993, 1:2,500 See drawing D07	No significant changes to site.	A residential property has been built 10m from the southeast boundary. An unidentified narrow structure is now mapped 50m to the southwest of the site.
2000, 1:10,000 *(Low resolution mapping)*	No significant changes to site.	A rectangular area of land has been sectioned off 30m to the southwest of the site next to the recently erected narrow structure.
2001, Satellite Imagery	No significant changes to site.	No significant changes to surrounds.
2006, 1:10,000	No significant changes to site.	The narrow structure and associated land is annotated 'The Stables' to the southwest of which two additional buildings have been constructed.
2006, Satellite Imagery	No significant changes to site.	No significant changes to surrounds.
2007, Satellite Imagery	No significant changes to site.	No significant changes to surrounds.
2009, Satellite Imagery	No significant changes to site.	No significant changes to surrounds.
2015, Satellite Imagery	No significant changes to site.	No significant changes to surrounds.
2016, Satellite Imagery	No significant changes to site.	No significant changes to surrounds.
2017, 1:10,000	No significant changes to site.	No significant changes to surrounds.

3.2. Present Land Condition

Table 3.2: Present Land Condition

Site Description	The site currently comprises two open fields with a dividing hedgerow extending north to south in the centre of the site. No buildings or structures are present with the site currently used by a farmer for grazing / arable farming.

Access	The site is accessed via two gated entrances along Well Street with an entrance into each of the fields. A third entrance is located in the northernmost corner providing access to the public footpath which crosses along the north of the site.
Boundaries	**north:** dense mature hedgerow with some trees extending onto neighbouring properties **east:** dense mature hedgerow with some trees extending onto neighbouring properties **south:** dense mature hedgerow with some trees extending onto Well Street **west:** dense mature hedgerow with some trees extending onto neighbouring property and open fields
Wayleaves	A footpath is mapped in the north of the site, extending east from the northwest corner before exiting the site in a central northern location onto Langford Crescent. The footpath originates from Well Street and continues north in the adjacent western field before crossing the site. It was observed during the site walkover that the wider side area is also used as an informal footpath with several dog walkers walking within the perimeter of the site.
Services / Utilities	Information regarding utilities has been provided by the client with overhead electric cables mapped and observed in the north of the site. Utility plans also show surface water and foul drains entering a combined sewer in the northeast corner of the site. No other services as mapped as being present within the site boundary.
Surfaces / Vegetation / Structures	The site surface consists of vegetated (grass) cover which appears to be in a healthy state with a mature hedgerow which splits the site into two halves. An area of possible disturbed ground is present in the southeast with a distinct patch of dock leaves, a biological indicator of disturbed ground. The site falls from north to south by approximately 3m with hummocky undulations generally present in the southern half. No exposed soils, anthropogenic materials of fly-tipped waste were observed on the site surface.

3.3. Historical Summary

3.3.1. The site does not appear to have been developed prior to, or since, the earliest available mapping (1871-78) having continually existed as two large fields.

3.3.2. Development surrounding the site has predominantly consisted of residential development to the east, north and west of the site, particularly after 1968, with agricultural land use to the southeast, south and southwest of the site. The only significant industrial development in the area has been coal mining, however, the nearest identified occurrence of this according to the reviewed historical mapping are shafts at an approximate distance of 400m to the south, and South Buckley Colliery approximately 670m to the northeast, all of which ceased to be operational prior to 1900.

3.4. Adequacy of Information

3.4.1. Whilst there are gaps in the historical map coverage, and there is limited information of former activities undertaken at the site, it is considered that the available information provides reasonable coverage of the history of the site and immediate surroundings to inform the assessment.

4. Site Characterisation

4.1. The environmental setting of the site is tabulated below:

Table 4.1: Environmental Setting

Site Setting and Topography	The site is located to the southwest of the town of Buckley, Flintshire with residential premises surrounding the site to the east, north and west and agricultural land / premises to the southwest, south and southeast. The site topography is shown on Ordnance Survey sloping from the north to the south at approximately 160m to 150m AOD.
Geology	BGS, historical OS mapping and site observations indicate the potential ground conditions to be: Superficial Deposits: Devensian Glacial Till (Diamicton) - unsorted glacial sediment. Bedrock: • Northeast: Gwespyr Sandstone - sandstone and interbedded argillaceous rocks. • Southwest: Pennine Lower Coal Measures Formation - mudstone, siltstone and sandstone. • South: Bowland Shale Formation – mudstone Faults: Two faults are mapped crossing the site with one traversing centrally from north to south between all three mapped bedrock types; the other, between the Gwespyr Sandstone and Bowland Shale Formations, crosses the south of the site from the eastern corner terminating when it encounters the other fault line. BGS Records The BGS borehole records show 16 entries (boreholes or trial-pits) arranged in a systematic grid across the site, although information pertaining to their findings is marked as confidential. The pattern of entries suggests that there has been previous investigation, possibly in 2002 as specified, to which the Council may have access. A geological log for the nearest available borehole located approximately 450m to the south recorded topsoil between 0.0-0.4m bgl, with red to brown stony clay (boulder clay) from 0.4 to 11.0m underlain by Coal Measures of dark grey mudstone.
Hydrology / Drainage	The only surface water course identified in the nearby vicinity of the site is a stream / drainage ditch which appears to originate from Bistre Cottage Farm 30m to the southeast; the historical mapping indicates the direction of flow is to

	the southeast. The site appears to be free draining with drainage anticipated to be predominantly via infiltration and sub-surface flow, however during periods of heavy rainfall surface run-off into the surface water drains along Well Street to the south may occur.
Flooding	Flood Risk Maps show that the site is at very low risk (<0.1% annual chance) of flooding from rivers and sea. The majority of the site is at very low risk (<0.1% annual chance) of flooding from surface water, however, a narrow channel crossing from the north to the south of the site has an increased chance of flooding designated between a low and high risk (0.1%-3.3% annual chance) with increased likelihood particularly to the south of the site. The site is not designated as being at risk of flooding from reservoirs.
Hydrogeology / Groundwater	The underlying superficial deposits are classified by the EA as unproductive strata. The underlying Gwespyr Sandstone and Pennine Lower Coal Measures are designated Secondary A aquifers (i.e. with permeable layers capable of supporting water supplies at a local rather than strategic scale), whereas the Bowland Shale formation is designated a Secondary Undifferentiated aquifer. The site is not located within a Source Protection Zone (SPZ) and the underlying bedrock is classified as a 'minor aquifer – low' with respect to groundwater vulnerability. A water abstraction point (groundwater) has been identified 70m to the east of the site in the grounds of Bistre Cottage Farm.
Radon	The site lies in an area where between 10 and 30% of properties are anticipated to be affected by radon gas ingress.
Excavation and Landfilling	No landfills within 0.5km of the site boundary were identified within the historic or present-day mapping, however, the Envirocheck report indicates two historic landfills in the vicinity of the site, one being 400m to the east, the other 440m to the west. Limited details are provided for the landfill to the east with the only information provided being that the accepted waste type was inert. The landfill to the west is of limited size but was operational prior to 1960 by Mold Urban District Council accepting inert, industrial, commercial, household and special waste. No evidence of historical excavations or extractions have been identified as having taken place on the site according to the review of historical mapping and information contained within the Envirocheck Report.
Mining	Pennine Middle Coal Measures underlie the site. The Coal Authority Report does not identify the site as being affected by past, present or future underground or open cast mining; no mine entries are present on or within 20m of the site boundary. A Coal Mining Risk Assessment for the site has been undertaken by specialist engineering geologist NKC Geotech Ltd. (ref. 1720), a

	copy of which is provided in Appendix C, along with the Coal Authority Report. The report should be read in its entirety but concludes that two coal seams underlie the site, the Half Yard Carl and its associated fireclays which were widely worked south of Buckley, and the Premier Coal, a 1.2m thick seam which has been extensively worked in the Buckley coalfield. The report continues that whilst neither the Coal Authority or Ordnance Survey have records of any mine entries on or close to the site, previous work by NKC in Buckley has proved extensive unrecorded past shallow mining activity within 15m of the surface which pre-dates the 19th century. Investigations on housing developments 300m to the east of the site has encountered shallow mineworkings and shallow shafts.
Nature Conservation	The northern part of the site is located within an SSSI impact risk zone relating to the Dee Estuary 9.9km to the north. No other statutory nature conservation sites, such as SSSIs, SPAs etc. have been identified within 500m of the site.
Ground Stability	Ground stability information provided within the Envirocheck Report (Appendix B) should be read in its entirety but in summary it indicates no hazard with regards to compressible ground or ground dissolution and a very low hazard with regards to collapsible ground, shrinking and swelling clays, landslide ground conditions and running sand.

5. Preliminary Conceptual Site Model

5.1. Conceptual Site Model

5.1.1. The conceptual model for the site describes the potential contamination sources, pathways and receptors. Development of a conceptual model is required in order to evaluate potential risk to receptors. The plausible sources, pathways and receptors are outlined below.

5.2. Sources of Contamination

5.2.1. The available information indicates that the site has not been developed prior to, or since, the earliest available mapping (1871-78) with the land having only seemingly been used for farming. Surrounding development is dominated by residential to the east, north and west, with limited agricultural related development to the south, southeast and southwest.

5.2.2. No conclusive observations of made ground or contaminative materials have been identified on site, however, an area of potentially disturbed ground was located to the southeast possibly indicating an area of made ground.

5.2.3. Coal mining has not been identified on or within the vicinity of the site during the historical map review or within the Coal Authority Report, however, as described in the NKC Coal Mining Risk Assessment, potentially viable coal seams do underlie the site and unrecorded shallow mining activity has been acknowledged in the general area. The potential for historic coal mining to have occurred on site or within the nearby surrounding area cannot therefore be fully discounted and neither can the presence of associated contaminative materials (i.e. mining spoil).

5.2.4. The site is located within an area where between 10% and 30% of properties are above the Radon Action Level.

5.3. Potential Targets

5.3.1. The proposed future use of the site is for residential development which would be considered as high sensitivity with respect to human health.

5.3.2. The principle receptors to any potential contamination would therefore be future site residents, however, construction workers, adjacent site users, built development, controlled waters and vegetation are also considered.

5.4. Human Health Risk Assessment

5.4.1. The potential for significant contamination to be present that may pose an acute risk to construction workers during the development is considered to be low. Similarly, future maintenance workers are unlikely to be exposed to materials with the potential to cause acute health impacts.

5.4.2. Made ground is not anticipated on site although could be present where the expected disturbed ground was identified and due to the potential for unrecorded historic coal mining in the area could be more widespread. If mining waste is present, such materials may contain elevated metal and poly-aromatic hydrocarbon (PAH) concentrations with the potential to pose an unacceptable risk to human health if retained at shallow depth in areas absent from permanent hardstanding such as gardens and/or public open space/landscaping.

5.4.3. Even though contamination on the site is considered unlikely, in order to determine the suitability of site soils for reuse within a sensitive land use (residential setting) chemical testing of shallow soils for a range of common contaminants (i.e. asbestos / PAHs / hydrocarbons / metals / metalloids) is required.

5.4.4. Risks associated with radon gas are dominated by possible diffusion into buildings from the underlying ground, and long-term inhalation exposure of residents.

5.5. Buildings & Structures

5.5.1. The site is located within an area where natural soils are classed as posing a very low hazard with respect to landslide, running sands, shrinking or swelling clay and collapsible ground hazards. No hazards are identified on site relating to compressible ground or ground dissolution.

5.5.2. The site is not located in an area where soils are anticipated to contain naturally high concentrations of sulphates or sulphides with the potential for concrete acid attack, however, the potential for pyritic conditions associated with mining spoil cannot be fully discounted without further investigation.

5.5.3. The potential exists for unrecorded shallow mine-workings which can cause local ground instability.

5.6. Controlled Waters Risk Assessment

5.6.1. The underlying bedrock types are classified as either Secondary A or Secondary Undifferentiated aquifers and are therefore considered as being of medium sensitivity.

5.6.2. The mapped presence of glacial till is anticipated to significantly inhibit the vertical migration of water into the underlying bedrock aquifer.

5.6.3. Flow to the nearest surface water course (the stream / drainage channel to the southeast) is probably via a combination of infiltration and sub-surface flow and run-off, although, no relevant pollution sources have been identified.

5.6.4. No viable water pollution sources have been identified, the site is therefore considered as being of low sensitivity with regards to risk to controlled waters.

5.7. Preliminary Conceptual Site Model

5.7.1. A preliminary conceptual site model (CSM) was derived for the site describing the potential contamination sources, pathways and receptors. The CSM was used to provide rationale for the site investigation design and is summarised below in Table 5.1:

Table 5.1: Preliminary Conceptual Site Model

Receptor	Source / Contaminant	Pathway / Exposure	Pollutant Linkage (in absence of mitigation)	Further Investigation
1. humans – construction workers	Metals / metalloids / asbestos / PAHs / hydrocarbons	Dermal contact / ingestion / inhalation – short term exposure	**Unlikely** – the presence of made ground / contaminants on site that pose acute risks to human health is not anticipated. BGS chemistry of natural soils does not indicate concentrations of metals to be present which pose a risk to human health.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.
2. humans – adjacent site users	Metals / metalloids / asbestos / PAHs / hydrocarbons	Wind blow / dermal contact / ingestion / inhalation	**Unlikely** – the presence of made ground / contaminants on site that pose significant risks to human health is not anticipated.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.
3. humans – future residents	Metals / metalloids / asbestos / PAHs / hydrocarbons	Dermal contact / ingestion / inhalation – long term exposure	**Unlikely** – the presence of made ground / contaminants on site that pose significant risks to human health is not anticipated.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.
	Ground gas (methane, carbon dioxide)	Accumulation within voids, confined spaces and service runs	**Unlikely** –made ground / natural sources not anticipated to be present on site and no significant off-site sources have been identified.	Ground investigation to confirm absence / presence of sources.
	Radon gas from natural ground	Accumulation within voids, confined spaces and service runs	**Possible –** between 10 and 30% of properties in area are expected to be above the Radon Action Level. Risks associated with radon gas dominated by diffusion into buildings from the underlying ground, and long-term inhalation exposure of residents.	Full radon protection measures to be installed in buildings.
4. property / services	Ground gas (methane)	Accumulation within voids, confined spaces and service runs	**Unlikely** – made ground / natural sources not anticipated to be present on site and no significant off-site sources have been identified.	Ground investigation to confirm absence / presence of sources.
	pH, sulphate	Chemical attack of buried concrete and plastic materials	**Unlikely** – natural soils / made ground with high sulphate concentrations not anticipated to be present on site.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.
4. vegetation / landscaping	Leachable phytotoxic metals	plant uptake	**Unlikely** – made ground / natural soils with concentrations of phytotoxic metals harmful to plant life not anticipated.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.

Receptor	Source / Contaminant	Pathway / Exposure	Pollutant Linkage (in absence of mitigation)	Further Investigation
5. ecosystems / protected species & habitats n/a – no ecosystems / protected habitats in immediate vicinity				
6. surface waters (stream / drainage ditch originating from 'Bistre Cottage Farm' to SE).	leachable metals / metalloids	migration via shallow groundwater / surface water run-off.	**Unlikely** – no viable water pollution sources identified.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.
7. groundwater – Bedrock (secondary A / secondary undifferentiated aquifers)	leachable metals / metalloids	migration via saturated zone	**Unlikely** – no viable water pollution sources identified.	Site investigation to include machine dug trial pits and soil sampling to determine ground conditions and soil chemistry.

6. Investigation Methodology

6.1. Objectives and Rationale

6.1.1. The site is being considered for residential development and is therefore considered to be of high sensitivity with respect to contamination.

6.1.2. Intrusive investigations have been undertaken to:

- confirm the shallow ground conditions underlying the site and provide information to inform appropriate foundation solutions for the site development;
- determine the presence, extent and nature of any made ground and soil chemistry of representative soils across the site;
- determine the physical suitability of the site for the proposed development and inform the remedial requirements necessary.

6.1.3. Soil sample collection was designed to:

- include samples from both the upper 1.0m of the soil profile and lower depths, for human health assessment purposes;
- include samples of foundation bearing strata for potential aggressive conditions for concrete;
- include any soils having contamination indicators; and,
- obtain representative samples of the various principal soil types present.

6.1.4. The investigation was carried out in accordance with the prescriptive brief provided by the client and completed under the appropriate guidance for site investigations (BS10175 and BS5930).

6.2. Fieldwork

6.2.1. A total of 12 machine dug trial pits were excavated on site on the 14th August 2017 under the supervision of SGP Consultants C Salwa and S Miller.

6.2.2. The positions of the exploratory holes were selected by SGP to provide a both good spatial coverage of the site achieving a spacing of 1 entry per 75m^2 and to specifically target the area of potentially disturbed ground identified during the walkover (TP5). The position of all trial pits undertaken at the site as part of this investigation can be seen on Drawing D08.

6.2.3. The trial pits were excavated with a 3CX JCB excavator to a maximum depth of 3m bgl from which small disturbed plastic tub, jar and bulk samples were collected for subsequent laboratory testing.

6.2.4. On completion, all trial pits were carefully backfilled, ensuring that excavated material was replaced in the same order as had been removed.

6.2.5. Representative jar samples were collected from the trial pits, five from the topsoil and five from the subsoil, to determine any potential soil contamination. These samples were submitted to Exova-Jones Environmental Laboratory (EJEL) for a typical suite of urban contaminants which included asbestos, metals / metalloids, speciated PAHs, BTEX and fractionated hydrocarbons. Six small disturbed tub samples were also collected from the subsoil for pH, sulphate and loss on ignition (LOI) analysis, also for submission to EJEL.

6.2.6. Geotechnical samples were collected from trial pits (disturbed bulk samples and small disturbed samples) and submitted to Professional Soil Laboratory (PSL) for geotechnical testing which included classification tests; particle size distribution, Atterberg limits (liquid limit and plastic limit), moisture content and compaction test of California Bearing Test - CBR.

6.2.7. Conclusions relating to ground conditions made within this report are based on data obtained from the site investigation, however it should be noted that variations, which affect these conclusions, may occur between and beyond the test locations.

6.3. Chemical Analysis

6.3.1. All chemical analysis of soils was carried out by Jones Environmental Laboratories, Queensferry, working where possible to MCERTS and / or ISO 17025 accreditation. Soil samples were stored in appropriate containers as advised by the laboratory, placed in a chilled cool box, and delivered to Jones Environmental within 12 hours of collection. Chain of custody documentation was completed and is retained by SGP. A summary of locations, strata and scheduling for soil and groundwater chemical analyses is provided below:

Table 6.1: Summary of Soil Chemical Analysis

Strata	Description	Sample ref	depth (m bgl)	analytical suite
Topsoil	Brown, slightly clayey, sandy TOPSOIL with occasional gravel (including red brick fragments in TP1) and frequent roots.	TP1-S1	0.1	SGP Suite
		TP4-S1	0.1	SGP Suite
		TP6-S1	0.1	SGP Suite
		TP8-S1	0.2	SGP Suite
		TP10-S1	0.1	SGP Suite
Subsoil	Firm-stiff, grey-brown, slightly gravelly, slightly sandy CLAY with occasional cobbles; gravel is sub-rounded limestone, sub-angular sandstone and mudstone and coal fragments.	TP2-S1	0.5	SGP Suite
		TP12-S1	0.5	SGP Suite
Subsoil	Soft to stiff grey - grey/brown (locally black), slightly gravelly CLAY with occasional cobbles and partings of orange silt / brown silty sand; gravel is sub-rounded limestone, sub-angular sandstone and mudstone and coal fragments.	TP1-S2	0.5-1.5	BRE Suite
		TP3-S1	0.9	BRE Suite
		TP4-S2	0.7	BRE Suite
		TP5-S1	0.8	SGP Suite + BRE Suite
		TP7-S1	0.5	SGP Suite
		TP7-S2	0.9	BRE Suite
		TP9-S1	0.6	SGP Suite
		TP10-S2	1.0	BRE Suite

SGP Suite = pH, metals / metalloids, PAHs (16 speciated), TPH CWG + BTEX, asbestos
BRE Suite = soluble sulphate (2:1 extraction), pH

7. Investigation Observations

7.1. Summary of Ground Conditions

7.1.1. The following information summarises findings of the site investigation carried out by SGP on 14th August 2017. The site work revealed that the general succession can be represented by a veneer of slightly clayey, sandy topsoil overlying Glacial Till (which is typically slightly sandy nearer the surface) with silty / sandy partings. No significant indicators of made ground were identified with the only such indicator being occasional red brick fragments observed in the topsoil of TP1 which is likely to have been tracked in to strengthen the field entrance. The full set of trial pit logs and photographs are included in Appendix D.

7.1.2. The only trial pit observed to deviate from the aforementioned soil profile was also TP1 where an isolated occurrence of peat was encountered encapsulated within very soft to soft clay, and where water ingress was encountered.

Topsoil

7.1.3. Topsoil was encountered at each test location from ground level down to depths of between 0.2m and 0.3m bgl, comprising a brown, slightly clayey, sandy topsoil with occasional gravel and frequent roots.

Alluvium and Peat

7.1.4. Possible alluvium was encountered in TP1 located in the depressed area of the plot. The alluvium comprised very soft to soft slightly sandy slightly gravelly clay with partings of silt and occasional cobbles with a layer of very soft fibrous peat between 1.5m and 2.1m bgl depth. Due to groundwater inflow to the trial pit the full thickness of alluvium and the depth of underlying Glacial Till was not proved in TP1.

Glacial Till

7.1.5. Glacial Till clay was encountered in each test location except the TP1 from between 0.2m and 0.3m bgl down to the base of the exploratory holes between 1.3m and 3m bgl. The full thickness of which was not proved during the ground investigation.

7.1.6. The Glacial Till encountered typically comprised of the following two types:

- Firm to stiff greyish brown slightly gravelly slightly sandy CLAY with occasional cobbles; gravel is sub-rounded limestone, sub-angular sandstone and mudstone and coal fragments. Encountered between 0.2m and 0.6m bgl in nine out of the twelve trial pits.
- Firm to very stiff grey - grey/brown (locally blackish dark brown) slightly gravelly slightly CLAY with occasional cobbles and partings of orangish brown silt / brown silty sand; gravel is sub-rounded limestone, sub-angular sandstone and mudstone and coal fragments. Encountered between 0.2m and 3m bgl in all trial pits.

7.2. Obstructions

7.2.1. No obstructions, relict structures or foundations were encountered within any of the trial pits.

7.3. Groundwater Conditions

7.3.1. Groundwater inflow was only recorded in TP1 entering at approximately 1.6m bgl through the stratum of peat.

7.4. Constraints

7.4.1. Ten out of twelve of the trial pits (TP3-TP12) were terminated due to clay very stiff consistency and hard digging conditions preventing further excavation at between 1.3 and 2.5m bgl.

7.4.2. The excavation of TP1 was terminated at 2.2m bgl due to the rapid inflow of groundwater.

8. Investigation Results

8.1. Results of Soil Chemical Analysis

8.1.1. The complete soil analytical data are presented in Appendix E.

8.1.2. The results of the soil analyses are compared to human health critical values (CVs) for initial screening purposes. Given the proposed residential development of the site, CVs devised for a residential scenario, primarily from the LQM / CIEH Suitable for Use Levels (S4ULs)[1] have been utilised. These are derived for a sandy loam soil; reference is initially made to the S4ULs derived for a soil with 1% soil organic matter (residential with garden-grown produce land-use) as a conservative assumption for screening purposes as this land-use assumes potential exposure to soils for young children.

8.1.3. The DEFRA published Category 4 Screening Level (C4SL) for lead in soils under residential land-use has been utilised to allow an initial screening for risk to human health. This is intended to demonstrate that land is not Contaminated Land as defined under Part IIA of the Environmental Protection Act. The adoption of the C4SL in a planning scenario has not been universally accepted, however in the absence of other generic screening criteria for lead following the withdrawal of the SGV by the EA it is considered appropriate to utilise the screening criterion.

8.1.4. Where published human health critical values are unavailable or inappropriate (because the substance does not significantly affect human health, but might influence other receptors), then other commonly used screening values are referred to, as noted below.

8.1.5. Given the high sensitivity of any future development, the presence of any detectable asbestos in garden soils is unlikely to be acceptable so the limit of detection has been adopted as a screening value.

8.1.6. The assessment criteria are intended for use for screening purposes only. Exceedances indicate that either more specific detailed site-specific risk assessment is required to better quantify risks to human health, or that remediation or mitigation is required to reduce risks by breaking the source-pathway-target relationship between solid phase contaminants and receptors. The results are summarised below:

Table 8.1: Summary of Soils Analysis

Contaminant	Number of Samples	Range of Concentrations (mg/kg or indicated)	Soil Standard Adopted and Concentration (mg/kg or indicated)	Exceedances
Arsenic	10	2.9-14	37 S4UL	None

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Contaminant	Number of Samples	Range of Concentrations (mg/kg or indicated)	Soil Standard Adopted and Concentration (mg/kg or indicated)	Exceedances
Cadmium	10	<0.1-0.4	11 S4UL	None
Chromium (total)	10	52.9-125.1	910 S4UL	None
Chromium (VI)	10	<0.3	6 S4UL	None
Copper	10	16-31	2,400 S4UL	None
			200 Defra Plant	None
Lead	10	15-827	200 C4SL	**TP1-S1 (250mg/kg), TP6-S1 (321mg/kg), TP8-S1 (827mg/kg), TP10-S1 (227mg/kg)**
Mercury (inorganic)	10	<0.1	40 S4UL	None
Nickel	10	11.1-25.1	130 S4UL	None
			110 Defra Plant	None
Selenium	10	<1	250 S4UL	None
Zinc	10	39-132	3,700 S4UL	None
			300 Defra Plant	None
Asbestos screen	10	NAD	NAD	None
Naphthalene	10	<0.04	2.3 S4UL	None
Acenaphthylene	10	<0.03	170 S4UL	None
Acenaphthene	10	<0.05	210 S4UL	None
Fluorene	10	<0.04	170 S4UL	None
Phenanthrene	10	<0.03-0.17	95 S4UL	None
Anthracene	10	<0.04-0.09	2400 S4UL	None
Fluoranthene	10	<0.03-0.42	280 S4UL	None
Pyrene	10	<0.03-0.32	620 S4UL	None
Benz(a)anthracene	10	<0.06-0.23	7.2 S4UL	None
Chrysene	10	<0.02-0.23	15 S4UL	None
Benzo(a)pyrene	10	<0.04-0.18	2.2 S4UL	None
Indeno(123cd)pyrene	10	<0.04-0.13	27 S4UL	None
Dibenzo(ah)anthracene	10	<0.04-0.04	0.24 S4UL	None
Benzo(ghi)perylene	10	<0.04-0.1	320 S4UL	None
Benzo(b)fluoranthene	10	<0.05-0.24	2.6 S4UL	None
Benzo(k)fluoranthene	10	<0.02-0.09	77 S4UL	None
Benzene	10	<0.005	0.087 S4UL	None
Toluene	10	<0.005	130 S4UL	None
Ethylbenzene	10	<0.005	47 S4UL	None
m/p-xylene	10	<0.005	56 S4UL	None
o-xylene	10	<0.005	60 S4UL	None
Aliphatic >C5-C6	10	<0.1	42 S4UL	None
Aliphatic >C6-C8	10	<0.1	100 S4UL	None

Contaminant	Number of Samples	Range of Concentrations (mg/kg or indicated)	Soil Standard Adopted and Concentration (mg/kg or indicated)	Exceedances
Aliphatic >C8-C10	10	<0.1	27 S4UL	None
Aliphatic >C10-C12	10	<0.2	130 S4UL	None
Aliphatic >C12-C16	10	<4	1,100 S4UL	None
Aliphatic >C16-C21	10	<7	5000[1] (65, 000 S4UL)	None
Aliphatic >C21-C35	10	<7	5000[1] (65, 000 S4UL)	None
Aromatic >C5-C7	10	<0.1	70 S4UL	None
Aromatic >C7-C8	10	<0.1	130 S4UL	None
Aromatic >C8-C10	10	<0.1	34 S4UL	None
Aromatic >C10-C12	10	<0.2	74 S4UL	None
Aromatic >C12-C16	10	<4	140 S4UL	None
Aromatic >C16-C21	10	<7-12	260 S4UL	None
Aromatic >C21-C35	10	<7-108	1,100 S4UL	None

Notes to table:

NAD: No asbestos detected

S4UL: LQM/CIEH Suitable for Use Levels (S4ULs), residential with homegrown produce landuse, (at 1% SOM). Copyright Land Quality Management Ltd. Reproduced with permission publication number S4UL 3102. All rights reserved.

C4SL: Category 4 Screening Levels published by CL:AIRE (C4SLs); 'residential with homegrown produce land use' (at 1% SOM)

DEFRA plant: Threshold guideline for the protection of sensitive plant species used by MAFF

1: Maximum limit of 5000 mg/kg included for reasons of amenity

8.1.7. Concentrations of the majority of determinands were below the respective assessment criteria based on a residential land use scenario with the exception lead within four out of the 10 topsoil samples (TP1-S1, TP6-S1, TP8-S1 & TP10-S1) exceedance concentrations ranging between marginal (227 mg/kg) and four times the adopted screening value (827 mg/kg).

8.1.8. No exceedances of the determinands were recorded within any of the subsoil samples collected.

8.2. Results of Soluble Sulphate Analysis

8.2.1. No samples contained water soluble sulphate in exceedance of the BRE Special Digest SD1 (2009) threshold of 0.5 g/l that would indicate the requirement of the use of sulphate resistant concrete within the development. The highest concentration was recorded at 0.0356 g/l in TP4-S2 at 0.7m depth.

8.2.2. Concrete classification risk assessment based on concentrations of soluble sulphate within the subsoil indicate a worst-case design sulphate class (DC) of DS-1. Based on the pH result obtained for the soils and assuming mobile groundwater within the natural ground, an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-2z is indicated as follows:

Table 8.2: Summary of Concrete in Aggressive Ground Assessment

Determinant	Number of Samples	Range Results (mg/l)	BRE SD1 sulphate assessment	
			Characteristic value (mg/l)	Table 5.2 classification
Soluble sulphate mg/l (2:1 extract)	6	11.3-35.6	35.6[1]	DS-1
pH (soils) – all soils	15	5.75-7.65	6.05[2]	AC-2z

1: highest result of data set; 2: characteristic value is the mean of the lowest 20% of the results; assumes natural ground location.

9. Geotechnical Assessment

9.1. General

9.1.1. We understand the anticipated development will comprise the construction of residential buildings, no proposed design has been specified at the time of writing.

9.1.2. The exploratory work from this investigation has proven the expected general strata sequence comprising a veneer of topsoil overlying typically firm to very stiff slightly sandy slightly gravelly clay of Glacial Till, with the exception of a low area in the south-eastern portion of the plot with very soft to soft slightly sandy slightly gravelly alluvium clay with a layer of fibrous peat.

Glacial Till

9.1.3. Encountered in eleven of the twelve trial pits from between 0.2m and 0.3m bgl down to the base of the exploratory holes between 1.3m and 3m bgl. The full thickness of which was not proved during the ground investigation. Represented in general by slightly sandy slightly gravelly clay with occasional cobbles.

9.1.4. Classification tests on selected samples revealed moisture content ranging from 12% to 18% with the fines fraction classified as a soil of low volume change potential (NHBC Building Standard, Chapter 4.2).

9.1.5. Full laboratory sieve analyses revealed the percentage of fines varying between 50% and 65%, the percentage of sand between 28% and 34% and content of gravel ranging from 3% to 21%.

9.1.6. Pocket penetrometer tests undertaken in the field revealed undrained shear strengths ranging from 100kPa to 220kPa indicating stiff to very stiff soils.

9.1.7. Loss on ignition tests revealed an organic content of between 1.5% and 5.8%.

9.1.8. The empiric correlations which include compression index, consistency index and liquidity index and based on laboratory test results indicate low compressibility, overconsolidated stiff to very stiff cohesive soils.

Alluvium and Peat

9.1.9. Encountered only in one location in TP1 located in the low area of the plot to the south-east.

9.1.10. The alluvium comprised very soft to soft slightly sandy slightly gravelly clay with partings of silt and occasional cobbles with a layer of very soft fibrous peat between 1.5m and 2.1m bgl depth.

9.1.11. Classification tests on a sample retrieved from TP1 indicate a soil with medium volume change potential, with higher content of fines (87%). The moisture content of this sample was of 30%.

9.1.12. Pocket penetrometer tests undertaken in the field in TP1 revealed undrained shear strengths ranging from 10kPa to 25kPa indicating very soft to soft soils.

9.1.13. The empiric correlations which include compression index, consistency index and liquidity index and based on laboratory test results indicate medium compressibility and normally consolidated clayey soil.

9.1.14. The above-mentioned results and correlations do not refer to a layer of highly compressible fibrous peat within much softer clay encountered in TP1.

Groundwater

9.1.15. Groundwater was encountered as inflow only in one of the twelve exploratory holes; in TP1 at 1.6mbgl. The rest of trial pits stayed dry during excavations.

California Bearing Ratio (CBR) Tests

9.1.16. CBR tests were undertaken in the alluvium and Glacial Till soils encountered at the site. Results of the testing ranged between 7.2% and 14.4% in the Glacial Till, and 0.9% in the alluvium.

Sulphate and pH Tests

9.1.17. Soluble sulphate tests carried out on soil samples recovered from the exploratory holes recorded values ranging from 11.3mg/l to 35.6g/l, in conjunction with pH values ranging from 5.8 to 7.7.

9.2. Site Excavation

9.2.1. Conventional hydraulic plant should be satisfactory for excavating service trenches within the natural soils.

9.2.2. In line with HSE guidelines, all excavations requiring personnel access should be adequately supported to avoid the risk of collapse. It has been proven during the ground investigation that excavations are stable within Glacial Till soils and unstable below groundwater level within alluvium.

9.2.3. Groundwater is expected to be encountered in a low area to the south-east of the plot at depths greater than about 1.6m bgl and dewatering may be required for excavations in this area. Conventional pumping from sumps should be satisfactory to maintain a dry excavation in that area at depths of up to 2m.

9.2.4. It should be appreciated however that seasonal variations may exist and hence groundwater entries may vary particularly during wetter months or after periods of inclement weather.

9.3. Foundation Solutions - Shallow Foundations

9.3.1. The alluvium to the south-east of the plot (TP1) is considered unsuitable as a bearing stratum due to its variability, low consistency, medium to high compressibility and potential for unacceptable total and differential settlement under applied foundation loadings. The depth and lateral extent of this deposit is unconfirmed and only a small proportion of the site is anticipated to be affected, however if the deposit exceeds 2m in depth alternatives to spread foundations such as traditional strips or trench block/fill may be required locally.

9.3.2. Elsewhere, the Glacial Till cohesive soils are considered to be a suitable bearing stratum for conventional shallow foundations at no less than 0.75m below existing ground level or 0.2m into the top of the formation, whichever is the deeper.

9.3.3. At this depth, a safe bearing capacity 150kPa may be adopted for foundations not exceeding 1m in width. This allows for a factor of safety of three against shear failure and for settlement generally not to exceed 25mm taking place over a number of years.

9.4. Ground Modification

9.4.1. Due to possibly limited extension of very soft alluvium soil with peat; removal and replacement by granular soil is considered to be a practical solution, depending on the depth of the material.

9.5. Ground Floor Slabs

9.5.1. Provided all the topsoil is stripped off, ground bearing floor slabs could be constructed placed on a layer of well compacted granular fill. However, where it is required to deepen the main foundations below 1.50m depth, due to the presence of vegetation or where seasonal desiccation is occurring then ground floor slabs will require suspending in accord with NHBC guidelines. A void should be left below the floor slab to accommodate future soil movements. This may also be achieved by use of a proprietary compressible material such as Clay board or Cellcore.

9.5.2. It should be noted that in accord with NHBC guidelines, a suspended floor slab will be required in soils with a volume change potential, even in the absence of trees and shrubs, where the soil is seasonally desiccated. Under those circumstances the adoption of a suspended slab is only likely to be avoided if construction of the floor slab takes place during the wetter times of the year. A void should be left below the floor slab to accommodate future soil movements.

9.5.3. The BGS advises that full radon gas protection measures are necessary.

9.6. Sub-Surface Concrete

9.6.1. With respect to BRE Special Digest 1 'Concrete in Aggressive Ground' (2005), chemical tests on selected soil samples have recorded soluble sulphate concentrations ranging from 11.3mg/l to 35.6mg/l. This would correspond to a Design Sulphate Class of DS-1.

9.6.2. The pH values ranged from 5.8 to 7.7. In terms of BRE Special Digest 1, the land has never been developed and may be considered to be natural ground. The groundwater beneath the site should be considered as mobile. The results correspond to Aggressive Chemical Environment for Concrete (ACEC) class AC-2z.

9.7. Access Roads and Parking

9.7.1. The structural design of a road or hard standing is based on the strength of the subgrade, which is assessed on the California Bearing Ratio (CBR) scale. With reference to Transport and Road Research Laboratory, Report LR1132, and laboratory classification tests it is recommended that for formation prepared in Glacial Till, a subgrade CBR value of 7% is adopted for preliminary design purposes based on equilibrium soil conditions, a thin pavement construction, low water table and average construction conditions.

9.7.2. The site conditions should be reassessed at the time of construction and the CBR/pavement design updated accordingly if considered necessary. Any areas of soft or deleterious material should be excavated and replaced with a properly compacted granular fill; this includes the area of soft ground identified near TP1.

9.7.3. The CBR value of 0.9% in the alluvium (south-eastern portion of the site) indicates very poor fine-grained soil of high compressibility and poor drainage which is considered unsuitable support for a pavement foundation. The minimum acceptable design CBR is 2.5% CBR.

9.7.4. The material at the surface can be removed and replaced by a more suitable material. If the depth of relatively soft material is small, it can be replaced in its entirety, although it may only be necessary to replace the top layer. The thickness removed will typically be between 0.5 and 1.0m.

9.7.5. Although the new material may be of better quality, the new Design CBR should be assumed to be equivalent to 2.5%, in order to allow for effects of any softer underlying material and the potential reduction in the strength of the replacement material to its long-term CBR value.

9.7.6. The following construction methods should be considered for pavement construction:

- Inspection of the formation and removal of any surface areas of soft, organic or other unsuitable materials.
- 'Heavy' proof rolling of the resultant formation, to compact loose granular materials and locate any soft spots at shallow depth beneath the formation for subsequent removal.
- Removal of intact or loose obstructions where noted at surface, or known based on the investigation, to a depth of at least 600mm beneath the formation to prevent the creation of hard spots or voiding.
- Backfilling of any excavation with well-compacted inert granular material.

10. Revised Conceptual Model and Risk Assessment

10.1. Methodology

10.1.1. Information from the current site investigation has been used to refine the likely source-pathway-target relationships identified in the preliminary Conceptual Site Model (CSM). A tier 1 risk assessment has been undertaken by comparison of contaminant concentrations in soils to generic screening criteria. These are values appropriate to the intended residential end-use of the site, and indicate whether potentially unacceptable risks to receptors are likely to exist, requiring either more detailed site-specific risk assessment or remediation to break the potential contaminant linkage.

10.2. Sources

10.2.1. The desk study indicated that the site has not been developed prior to, or since, the earliest available mapping with the land having only seemingly been used for farming. The intrusive site investigation has not indicated anything to the contrary with no significant observations of made ground or contaminative materials, including in the area of potentially disturbed ground. This also alludes to the site soils not being impacted by historical coal mining as there were no observations of mining spoil. This has been confirmed by the soil chemical analysis undertaken which did not indicate elevated concentrations of associated contaminants (metals or PAHs) with the exception of lead, the presence of which is discussed below.

10.2.2. The general succession of ground can be represented by a veneer of slightly clayey, sandy topsoil overlying boulder clay (which is typically slightly sandy nearer the surface) with silty / sandy partings.

10.2.3. An isolated occurrence of peat encapsulated within the area of soft clay was observed in TP1 in the southwest of the site which has the limited potential for ground gas generation (i.e. carbon dioxide and methane). Based on observations of the ground conditions within the other trial pits it is anticipated that this occurrence is highly localised and generation rates from such sources are typically very low.

10.2.4. Concentrations of the majority of determinands were below the respective assessment criteria based on a residential land use scenario with the exception of exceedances of lead within four out of five of the topsoil samples. Due to the limited development of the site and surrounds and the absence of made ground the origin of the lead contamination is unclear and may be derived from natural sources.

10.2.5. The site is located within an area where between 10 and 30% of properties are above the Radon Action Level.

10.3. Targets

10.3.1. The proposed future use of the site is for residential development which would be considered as high sensitivity with respect to human health.

10.3.2. The principle receptors to any potential contamination would therefore be future site residents, however, construction workers, adjacent site users, built development, controlled waters and vegetation are also considered.

10.4. Human Health Risk Assessment

10.4.1. The majority of soil contaminants were recorded at concentrations below the human health assessment criteria for a sensitive residential land-use with the exception of elevated lead (227-827 mg/kg) within the majority of the topsoil samples. The risk to human health from lead contaminated topsoil is probably limited to children, infants and foetuses, however as lead is increasingly recognised as non-threshold substance with respect to impacts to cognitive development, further assessment may be appropriate to confirm risks and appropriate remedial actions.

10.5. Ground Gas / Vapour Risk Assessment

10.5.1. The only viable source of ground gas generation identified is the peat observed in TP1 which is anticipated to be highly localised but could potentially exist within pockets across the site. However, as described in the Ground Gas Handbook (Wilson, Card and Haines, 2009), the gas generation potential of peat is low to very low, the level of risk to onsite development is low (especially as the overlying clay will substantially inhibit vertical migration and radon protection measures are required within all built development, see below), and the risk of lateral migration is negligible. The risk presented by the peat to human health is therefore considered to be low, but should be reduced further via the removal of these deposits to improve the geotechnical properties of the groundf.

10.5.2. The site is located within an area where between 10 and 30% of properties are above the Radon Action Level. Full radon protection measures are to be installed in all buildings as recommended within BRE 211 - Radon: Guidance on Protective Measures for New Buildings (2007).

10.6. Property Risk Assessment

10.6.1. The proposed redevelopment of the site is anticipated to include residential properties with associated infrastructure (e.g. roads, drainage infrastructure, utility services).

10.6.2. The risk presented to built development by the peat identified via the production of methane to explosive concentrations is considered to be very low and will be reduced further.

10.6.3. Concrete classification risk assessment based on concentrations of soluble sulphate within the natural soils indicated design sulphate class (DC) of DS-1 and a worst case Aggressive

Chemical Environment for Concrete (ACEC) classification of AC-2z. No other specific risks of chemical attack on other construction materials or pipeline materials have been identified.

10.7. Controlled Waters Risk Assessment

10.7.1. Contamination of the site is limited to the presence of elevated lead, the potential migration of which into either groundwater or surface water is considered to be negligible, especially when considering the limited vertical migration offered by the presence of cohesive soil deposits (boulder clay) across the site.

10.7.2. The potentially significant pollution linkages are summarised in Table 10.1 below:

Table 10.1: Updated Conceptual Site Model

Receptor	Source / Contaminant	Pathway / Exposure	Pollutant Linkage (in absence of mitigation)	Further Investigation / Remediation
1. Humans – construction workers	Lead	Dermal contact / ingestion / inhalation – short term exposure	**Unlikely** –Exceedances of screening criteria for lead detected within the topsoil do not indicate risks to adult workers whose exposure durations and frequencies are reduced and who are less sensitive to exposure.	Concentrations of lead were not recorded at levels which may pose an acute risk. Good occupational hygiene and correct PPE to be implemented during development phase of works to reduce exposure to site workers.
2. humans – adjacent site users	Lead	Wind blow / dermal contact / ingestion / inhalation	**Very unlikely** – Multiple exceedances of screening criteria for lead detected within the topsoil, however, impact of wind blow is likely to be limited.	Concentrations not recorded at acute levels; no mitigation measures required
2. Humans – future site residents	Lead	Dermal contact / ingestion / inhalation – long term exposure	**Possible** – Multiple, mostly minor exceedances of screening criteria for lead detected within the topsoil.	Based on current information material must be assumed to be unsuitable for retention within gardens / landscaped areas without further testing / assessment. Further testing of soils for lead only, statistical interpretation of the significance of exceedances, and possibly bioavailability testing may indicate risks do not require specific mitigation measures, however for now it should be assumed that clean soil cover will be required for private gardens.
	Ground gases (CH_4 and CO_2)	seepage into building via foundations, indoor inhalation	**Unlikely –** localised deposit of peat identified which has a low to very low potential for ground gas generation. Potential for other deposits exists within the site.	Removal of peat deposit in southwest of site and wherever encountered during development phase of works. Radon protection measures required within all buildings which will provide precautionary mitigation
	Radon gas from natural ground	Accumulation within voids, confined spaces and service runs	**Possible** – between 10 and 30% of properties are above the Radon Action Level.	Full radon protection measures to be installed in buildings.

Receptor	Source / Contaminant	Pathway / Exposure	Pollutant Linkage (in absence of mitigation)	Further Investigation / Remediation
3. Property / services	pH, sulphate and organic contaminants	Chemical attack of buried concrete and plastic materials	**Very unlikely** – no significant concentrations of substances which could attack concrete have been recorded or which would require the use of protective water pipes	no action required
	Ground gas (CH_4)	Accumulation of methane to explosive concentrations.	**Very unlikely** – localised deposit of peat identified which has a low to very low potential for ground gas generation. Potential for other deposits exists within the site.	Removal of peat deposit in southwest of site and wherever encountered during development phase of works. Radon protection measures required within all buildings which will provide precautionary mitigation
4. Vegetation / landscaping	Phytotoxic metals (i.e. copper / nickel/ zinc)	plant uptake	**Very unlikely** – concentrations of phytotoxic metals within site soils below Defra/MAFF threshold values.	Imported topsoil likely to be required for placement within all garden/landscaped areas which should be tested to determine the suitability for use within the site
5. Ecosystems / protected species & habitats n/a – no ecosystems / protected habitats in immediate vicinity				
6. surface waters (stream / drainage ditch originating from 'Bistre Cottage Farm' to SE).	Lead	migration via groundwater in granular horizons of boulder clay, drains and surface runoff	**Very Unlikely** – boulder clay deposits are anticipated to have limited permeability and will therefore retard the vertical movement of contaminants. Concentrations of lead within the soils are not likely to be significant within the context of the wider surrounding area.	no action required
7. groundwater – Bedrock (secondary A / secondary undifferentiated aquifers)	Lead	migration via granular horizons in boulder clay	**Very Unlikely** – boulder clay deposits are anticipated to have limited permeability and will therefore retard the vertical movement of contaminants. Concentrations of lead within the soils are not likely to be significant within the context of the wider surrounding area.	no action required

11. Conclusions and Recommendations

11.1. Conclusions

11.1.1. The investigation has indicated that the site has not been developed prior to, or since, the earliest available mapping (1871-78) with the land having only seemingly been used for farming. It was suspected that prior to the earliest mapping the site may have been impacted by historic coal mining, however, the ground investigation identified no evidence to support this.

11.1.2. Surrounding development is dominated by residential to the east, north and west, with limited agricultural related development to the south, southeast and southwest.

11.1.3. Natural ground conditions encountered were consistent throughout the site comprising a veneer of slightly clayey, sandy topsoil overlying boulder clay (which is typically slightly sandy nearer the surface) with silty / sandy partings.

11.1.4. No significant deposits of made ground have been identified on site and concentrations of the majority of determinands were below the respective assessment criteria based on a residential land use scenario, however, exceedances of lead have been detected within four out of 10 of the soil samples with all the incidences occurring in topsoil. Further assessment can confirm whether the levels, distribution and form of lead present requires remedial mitigation measures.

11.1.5. The only viable source of ground gas generation identified is the peat observed in the south west part of the site. This is anticipated to be highly localised but could potentially exist within pockets across the site. The gas generation potential of peat is low to very low, the level of risk to onsite development is low and the risk of lateral migration is negligible. The risk presented by the peat to human health is therefore considered to be low.

11.1.6. The site is located within an area where between 10 and 30% of properties are above the Radon Action Level.

11.2. Recommendations

11.2.1. Elevated lead in exceedance of human health criteria have been recorded within the site topsoil, however the testing frequency carried out to date is limited with 1 sample collected per 2,600m^3 topsoil (assuming site area of 15,000m^2 with average 0.3m thickness of topsoil = 15,600m^3 topsoil).

11.2.2. Further testing and statistical assessment of the results, or assessment of the bioavailability of the lead for uptake, may allow further assessment for the reuse of topsoil within a residential development. Testing on a denser grid (20m) of topsoil for lead only should improve confidence in the distribution of lead in the topsoil and what representative concentrations

should be used in risk assessment, however based on the testing to date the soil must be assumed to be unsuitable for use and mitigation measures will be required in order to reduce the potential risk to future site occupants.

11.2.3. This is could involve the stripping of topsoil and replacement of clean imported material within private garden areas. Site topsoil based on the concentrations recorded within this investigation would be classed as non-hazardous waste so the exercise would not be an unacceptable constraint to development or render redevelopment of the site uneconomic.

11.2.4. The site appears to present no risk of contamination of drinking water supplies, and normal PE water main pipe materials should be appropriate.

11.2.5. Peat deposits should be removed from the southwest of the site and wherever encountered to reduce risks to human health and any built development should the site be developed as intended.

11.2.6. Full radon protection measures are to be installed in all buildings as recommended within BRE 211 - Radon: Guidance on Protective Measures for New Buildings (2007).

11.3. Recommendations for Foundations and Site Engineering

11.3.1. The Glacial Till is considered to be a suitable bearing stratum for conventional shallow foundations at no less than 0.75m below existing ground level or 0.2m into the top of the formation, whichever is the deeper. At this depth, a safe bearing capacity 150kPa may be adopted for spread foundations (traditional strips) not exceeding 1m in width.

11.3.2. With reference to Transport and Road Research Laboratory, Report LR1132, and laboratory classification tests it is recommended that for formation prepared in Glacial Till, a subgrade CBR value of 7% is adopted for preliminary design purposes based on equilibrium soil conditions, a thin pavement construction, low water table and average construction conditions.

11.3.3. The CBR value 0.9% in the alluvium (south-eastern portion of the site) is considered unsuitable support for a pavement foundation. The minimum acceptable design CBR is 2.5% CBR.

11.3.4. The apparently localised alluvium to the south-east of the site is considered unsuitable as a bearing stratum for structures and pavements due to its variability, low consistency, medium to high compressibility and potential for unacceptable total and differential settlement under applied loadings. The lateral and vertical extent of this deposit should be confirmed, and its removal and replacement with engineered fill may be appropriate if only implied volumes are present. Alternatively deepening of foundations or alternative techniques for pavement construction may be considered.

11.3.5. Conventional hydraulic plant should be satisfactory for excavating service trenches within the natural soils.

11.3.6. Groundwater is expected to be encountered as seepages at depths greater than about 1.6m in the depressed area to the south-east of the site and dewatering/support of excavations below this depth is likely to be required.

11.3.7. Further investigation is recommended to determine to total depth and lateral extension of very soft to soft alluvium soils with layers of peat.

11.3.8. The Coal Mining Risk Assessment for the site carried out by NKC Geotech Ltd (report reference: 1720; August 2017) recommends an intrusive investigation to determine the geology and prove the depth or absence of shallow mineworkings in the Half Yard and Premier Coal seams. It is also advised that a site-specific Coal Authority Permit is required before any such intrusive investigation work is carried out. For full details please refer to the original report.

11.3.9. Results of chemical testing on selected samples of natural soils correspond to Design Sulphate Class of DS-1 and a worst case Aggressive Chemical Environment for Concrete (ACEC) classification of AC-2z.

11.4. Limitations

Stratigraphy

11.4.1. The evidence of stratigraphy is taken from discrete locations, and from information provided by other parties. Whilst it is usually reasonable to infer that similar conditions may extend between these locations; caution should be exercised.

Contamination

11.4.2. The site investigation involved sampling at discrete locations, and it should be recognised that further areas or types of contamination may exist between investigation positions. The analyses performed are drawn from a typical suite of tests used to screen potentially contaminated land, and specified to fall within the available budget. It is always possible that other substances may be present that have not been included within the standard range of tests.

General

11.5. This report has been prepared by SGP for the sole and exclusive use of the Denbighshire County Council. Reasonable skill, care and diligence has been exercised within the budget available, and in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team in undertaking the assessment and preparing this report, it is possible that other ground conditions and contamination as yet undetected may exist. Reliance on the findings of this report must therefore be limited accordingly. Such reliance must

be based on the whole report and not on extracts which may lead to incomplete or incorrect conclusions when taken out of context.

11.6. SGP reserves the right to alter any of the foregoing information in the event of new information being disclosed or provided and in the light of changes to legislation, guidelines and responses by the statutory and regulatory authorities.