

Our ref: 7791si-A

Site Investigation Report

for land off

Gatewen Road,

Wrexham

For: Bellway Homes (North West)
2 Alderman Road
Speke
Liverpool
L24 9LR

24th September 2021

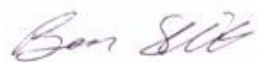
Site Investigation Report for land off
Gatewen Road, Wrexham.

Document Verification

Project Title	Gatewen Road, Wrexham.
Project Number	7791
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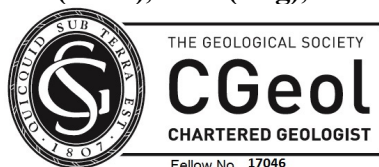
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*1 – For details of revision changes refer to end of Section 1 – Introduction.

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1.0 Introduction

This report is the findings of a site investigation on the ground conditions, contamination aspects and anticipated engineering/foundation requirements for a proposed residential development on land off Gatewen Road, Wrexham.

The site is proposed for residential development by Bellway Homes (North West), comprising of 112 No. residential plots, of which 88 No. are traditional residential properties with the remaining plots within 2 No. apartment blocks. The housing includes a combination of traditional detached, semi-detached and 3-6 block mews residential houses with associated roads, private driveways, garages, gardens and landscaping. The proposed development layout is shown on APD Drawing "Planning Layout", referenced BHNW130. PL01, revision A, dated 24 September 2021. An extract of which is overlain on Coopers Drawing No. 7791/Fdz, within Appendix 15. It is also assumed that all materials and workmanship will comply with the Building Regulations and the NHBC Standards.

The copyright of this report and the associated plans/documents prepared by Coopers (Chester) Ltd, hereafter referred to as Coopers, and is solely owned by Coopers. Consequently, neither this report nor the associated plans/documents may be reproduced, published or adapted without the express written approval of Coopers. Complete copies of this report may, however, be made and distributed by our client as an expedient in dealing with matters directly related to its commission.

The accuracy of map extracts cannot be guaranteed and it should be recognised that different conditions on /adjacent the site may have existed between and subsequent to the various map surveys. Historical map extracts are produced as an appendix Report by Groundsure under licence from Ordnance Survey. Coopers can reproduce and use these extracts in this report under their Ordnance Survey Licence No. AL100005579.

Where data supplied by others, including that from previous investigations, has been used it has been assumed that the information is correct. No responsibility can be accepted by Coopers for inaccuracies within the data supplied by others. We would advise that our client makes their own detailed enquiries to the Local Authorities to determine any additional planning constraints which may be applied to this site and which have not been identified within this report.

The results of the exploratory holes explorations are based upon the facts established from observations and field tests. It should be recognised that strata may vary considerably from point to point and the groundwater regime may be influenced by seasonal or other factors. While every attempt is made to assess the likelihood and extent of such variations, conditions may nevertheless exist which are undisclosed by this investigation.

This report has been prepared in accordance with the Building Regulations Part C (2004), and complies with the requirements associated with the planning guidance. This report should address the conditions placed within the planning conditions regarding the ground conditions and contamination. This report has been prepared in accordance with the requirements of the NHBC Standards, Chapter 4.1. The scope of this report complies with the criteria for certification under the Initial Assessment including the Desk Study (D1), the Walkover Survey (D2), and the Basic Investigation (D4). This report constitutes a Phase I and II report in accordance with LCMR. The report is also prepared in accordance with BS10175: 2011+A2:2017, and complies with Phase 1 (Preliminary Investigation), and Phase 2 (Exploratory Investigation) investigation.

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The further actions deemed necessary to be completed prior to development of the proposed site for residential development have been listed in Section 27 of this report. The full extent of further actions may not be limited to those issues stated and, during the course of the development, additional further actions may be required.

The report should be read in its entirety, including all associated drawings and appendices. Coopers cannot be held responsible for any misinterpretations arising from the use of extracts that are taken out of context.

Arboricultural Survey and advice on arboricultural issues are considered to be outside the scope of this report except for their effect on the foundations to the proposed buildings. Where identification of any species is made, especially invasive plants such as Japanese Knotweed, Himalayan Balsam or Giant Hogweed, this should only be considered as a preliminary assessment and subject to confirmation by a professional Arboriculturist. Coopers take no responsibility for failing to identify, or the incorrect identification of, any tree or plant species on site.

This report is prepared and written in the context of the purposes stated above and should not be used in a different context. Furthermore, new information, improved practices and legislation may necessitate an alteration to this report in whole or in part after its submission. Therefore, with any change in circumstances or after the expiry of one year from the date of this Report, the report should be referred to Coopers for reappraisal.

The Revision A of this report was provided following an update to the proposed development layout and associated drawings and references.

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2.0 Executive Summary

Grid Reference	SJ 313 516 (Refer to Drawing No. 7791/L1 in Appendix 15).
Approximate Area	4.81 Hectares (11.89 acres).
Development Proposals (Section 3)	The site is proposed for residential development by Bellway Homes, comprising of 112 No. residential properties, including 88 No. traditional houses, with 2 No. apartment blocks.
Site Investigation Data (Appendices 4, 5, 6 and 12)	Coopers undertook the following: • 5 No. small diameter boreholes (referenced WS01 to WS05) up to 4.45m in depth. • 15 No. trial pits (referenced TP01 to TP15) up to 2.9m in depth. • 4 No. infiltration test pits (referenced ITP01 to ITP04) up to 2.55m in depth. • 2 No. hand dug pits (referenced HDP1 and HDP2) up to 0.5m in depth.
Site Description (Sections 4 and 5)	The site consisted of agricultural fields utilised for horse grazing, a well and surface walls associated with a former reservoir were present close to the north eastern site boundary, with areas of trees and unknown small brick structure within the central part of the site.
Site History (Section 7)	Agricultural fields from Tithe maps of 1844 to present. Reservoir recorded in the north eastern part of the site by 1910, anticipated to have been for steam engines on the adjacent mineral railway for Gatewen Colliery to the east of the site. The colliery closed in 1932 and was subsequently used as a coal crushing plant prior to development by Bloor Homes in phases from 2007.
Hazardous Installations and Development Constraints (Section 8)	No identified hazardous installations or significant development constraints. Recorded former asbestos cement water pipe in the south east of the site, requires removal and soil testing to confirm no residual impacts/soil contamination. It is advisable to hold consultation with the local authority regarding any specialist reports or information needed in relation to the proposed development.
Utility Locations (Section 8.0)	Live services are recorded within the site, including potable water and foul sewers within the south eastern corner.
Landfill Sites & Ground Gases (Section 9 and 17)	No landfill sites or significant hazardous ground gases likely with the exception of full radon required for all residential houses and apartments. Gas monitoring is ongoing to confirm no coal mine gas emissions are present, based upon 3 No. monitoring visits to date no significant hazardous ground gases have been identified and therefore would not require gas mitigation measures beyond that of full radon mitigation. Construction details for full radon have been provided in Appendix 15
Geology, Hydrology & Hydrogeology (Section 10)	Drift – Combination of fluvioglacial sands and gravels and glacial till. Bedrock – Pennine Lower Coal Measures – Mudstone, Siltstone and Sandstone. Geological Faults – recorded to terminate in the southern part of the site, running north/south. Groundwater – Site not within a groundwater source protection zone. Drift designated as Secondary Aquifer (undifferentiated) and Secondary A Aquifer, bedrock designated as Secondary A Aquifer. No active groundwater abstraction licenses recorded. Hydrology – Closest watercourse is unnamed tributary of River Gwenfro, situated 221m to the north east of the site. Flood Risk – Outside of recorded zones of flooding from rivers, seas or reservoirs. Compressible Ground and Subsidence Hazards – Environmental data reports references very low to negligible risks, with the exception of landslides where part of the site is designated as at low risk. Mineral Safeguarding – No likely defined significant mineral resources. Oil and Gas Production – Outside of defined areas of oil and gas production.
Environmental, Archaeological, Ecological and Conservation Issues (Section 11)	Environmental reports reference the area of Gatewen Marsh, 219m to the north east of the site is designated as a Site of Special Scientific Interest. 2 No. areas of designated ancient woodland recorded, at least 169m from the site. No significant archaeological conditions likely. Consultation with specialists in these fields and Local Authority regarding any limitations or requirements for additional surveys and assessments.
Coal Mining and Brine Extraction (Section 12)	Brine Subsidence – The site is not within a zone of potential impact from brine subsidence. Coal Mining – The site is within a Coal Authority reporting area. The Coal Authority mining report details that coal mining was undertaken from 100m to 230m, last worked in 1932. The site is defined as outside of a high risk development area, therefore no special precautions anticipated.
Radon (Section 13)	10-30% of buildings above action threshold – Full Radon Protection Measures are required.

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Ground Conditions (Section 15)	Topsoil – 0.2m to 0.3m, present across the site, excluding former reservoir. Madeground – Only identified within area of former reservoir (depth unknown), comprised of gravels of ash and clinker, with brick, glass and timber. Natural Drift Strata – combination of firm, firm to stiff and stiff glacial clays and loose to medium dense, or medium dense sands and gravels. Bedrock – not encountered, based upon desk study data bedrock is anticipated to be between 5m below ground level in the west to 15m in the east. Groundwater – None encountered to 4.45m.
Contamination and Waste (Sections 16, 18 and 19)	Conceptual Model – Primary risks associated with reworked madeground localised around the reservoirs. Contamination Testing – No contaminants identified relative to residential garden thresholds. Remediation – None Required. Waste – Cut and Fill proposals indicate surplus of soils where no imported soils are likely. The cut and fill works will include reuse of soils where Material Management Plans would be required with CL:AIRE registered DoW-CoP. Soil Disposal – Should soil disposal be required the majority of the soils would likely be designated as inert or non-hazardous waste. Potable Water – Potable water supply pipelines are expected to be standard Polyethylene pipes (no volatile or mobile contaminants). Further Works – recommend soil testing following removal of cement asbestos pipeline in the south eastern part of the site.
Sub-Soil Classification (Section 20)	<u>Concrete Classification (Based on BRE Special Digest 1 (2005))</u> Fluvioglacial Sand/Gravel – DS2, AC-2, DC-2 Glacial Clay - DS-1, AC-1s, DC-1s <u>Shrinkage Potential</u> Glacial Clays – Low Shrinkage Potential
Trees (Section 21)	Trees present on and adjacent to the site with potential influence on foundations. Agree requirements for tree root protection and any felling with local authority.
Ground Floor Slabs (Section 22)	Based upon our client's preferred floor slab construction the following slab types are proposed: • Precast Suspended Floor Slabs (block and beam). All ground floor slabs to residential houses and apartments to include full radon mitigation measures.
Anticipated Foundations (Section 23)	Foundation Types: The proposed foundation types are recorded on coopers Foundation Zone Plan in Appendix 15. The main items influencing the foundation types are proposed cut and fill, combined with tree influence. Foundation types include: • Nominally Reinforced Strip Foundations • Mass Concrete Trench Fill Foundations (including areas with heave mitigation to the floor slabs) • Doubly Reinforced Strip Foundations on Vibro Stone Columns. • Piled Foundations with Associated Ground Beams (including areas with heave mitigation to the ground beams and designs for negative skin friction to the pile lengths).
Dewatering and Trench Side Stability (Section 24 and 25)	Trench Stability – Low trench stability, where being left open to be fully supported or battered (where feasible to do so). Dewatering – no groundwater encountered, any localised perched waters likely to be viable for conventional sump pumping. Traditional soakaways – In situ testing (BRE 365) has confirmed traditional soakaways are viable where they intercept layers of sands and gravels.
Road Sub-Grade (Section 26)	Following site clearance, vegetation removal and earthworks regrading levels the anticipated roads and car parking sub-grade materials are likely to comprise natural or reworked clays and sands. CBR values of up to 5% in natural clay and up to 20% in natural sand based upon text book values. Materials to be placed in road corridors will require placement and rolling to an engineering specification.
Further Actions (Section 27)	Further action which Coopers consider will be required to progress the development status could include, but not necessarily be limited to: - • Submit site investigation report for local authority and NHBC for approval. • Report on findings from ongoing gas monitoring. • Consultation with Local Authority and National Resources Wales regarding proposals for use of CL:AIRE Definition of Waste – Code of Practice (DoW-CoP). • Produce Material Management Plan (MMP) for the reuse of soils on site. • Registration of MMP following DoW-CoP. • Undertake testing of soils following removal of asbestos cement pipeline. • Installation and verification of full radon mitigation measures in accordance with BRE211 and CIRIA C735.

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3.0 Proposed Development

(Refer to Appendix 15)

The site is proposed for residential development by Bellway Homes (North West), comprising of 112 No. residential plots, of which 88 No. are traditional residential properties with the remaining plots within 2 No. apartment blocks. The housing includes a combination of traditional detached, semi-detached and 3-6 block mews residential houses with associated roads, private driveways, garages, gardens and landscaping. The proposed development layout is shown on APD Drawing "Planning Layout", referenced BHNW130. PL01, revision A, dated 24 September 2021, an extract of which is overlain on Coopers Drawing No. 7791/Fdz, within Appendix 15.

4.0 Site Location

(Refer to Appendix 15)

The proposed development is located at National Grid Reference SJ 313 516, situated to the north of Gatewen Road (B5433), in New Broughton, Wrexham, approximately 2.29km to the west of Wrexham Town Centre. The location of the site is shown on Drawing No. 7791/L1 in Appendix 15.

The surrounding area was primarily residential housing, with an area of playing fields to the west of the site, and a wooded embankment to the east/north.

5.0 Site Description

(Refer to the Site Plan in Appendix 15)

5.1 Site Walkover

A site walkover was undertaken by Coopers on 14th May 2021.

At the time of the walkover the site consisted of pastoral land, used for the grazing of horses. The site generally constituted two sloping areas with a central plateau, one facing west and one facing east. Within the slope facing the west, an escarpment formed trending north from beyond a brick structure and a central copse of trees. The escarpment faded out before it reached the northern site boundary, as the site levelled off. The northern, eastern and eastern half of the southern site boundary were all forested, with the remaining boundaries consisting of the western and western half of the southern boundary being generally clear of vegetation except for the occasional lone tree. A mixture of wooden pole fencing secured with barbed wire and wooden panel fencing spanned the perimeter of the site.

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Photographs 1 and 2: Showing the general nature of the site, and the central wooded copse and miscellaneous brick structure

A second wooded copse was present adjacent to the eastern site boundary, with evidence of made ground at the surface and uneven ground. This relates to a historic reservoir, which was partially infilled (or covered) and was still visible on site. The reservoir structure was circular and the external walls were of brick construction. A smaller circular feature immediately adjacent to the east of the reservoir was also of brick construction, and a metal pipe was visible inside of it penetrating the brick wall toward the historic reservoir. The smaller circular feature was not infilled to the surface, and contained predominantly tree branches and miscellaneous anthropogenic waste.



Photograph 3: Showing the partially infilled reservoir and the eastern wooded copse



Photograph 4: Showing the smaller circular brick structure adjacent to the infilled reservoir

Beyond the eastern site boundary was a wooded slope, which transitions downwards into a public footpath constructed on the location of a former mineral railway. This footpath was approximately 2-4m lower than the site. A wooded slope was also present along a portion of the southern site boundary where it bordered Gatewen Road, to the east of the site entrance off Gatewen Road. To the west of the site entrance, the site was embanked below Gatewen Road, with manhole covers visible periodically on the raised section. In the far west corner, a wooden pole electricity transformer was present.

A photograph of a paved path lined with lush green trees and foliage. A tall, thin white pole stands on the left side of the path. The path leads into the distance, flanked by more trees and a building visible in the background.

Photograph 5: Showing the wooded slope beyond the eastern site boundary and the public right of way

6.1 Summary of Previous Investigations On/Close to Site:

Coopers have undertaken investigation works on behalf of residential developments close to the site from 1995 onwards, the locations of which are shown on Figure 1.

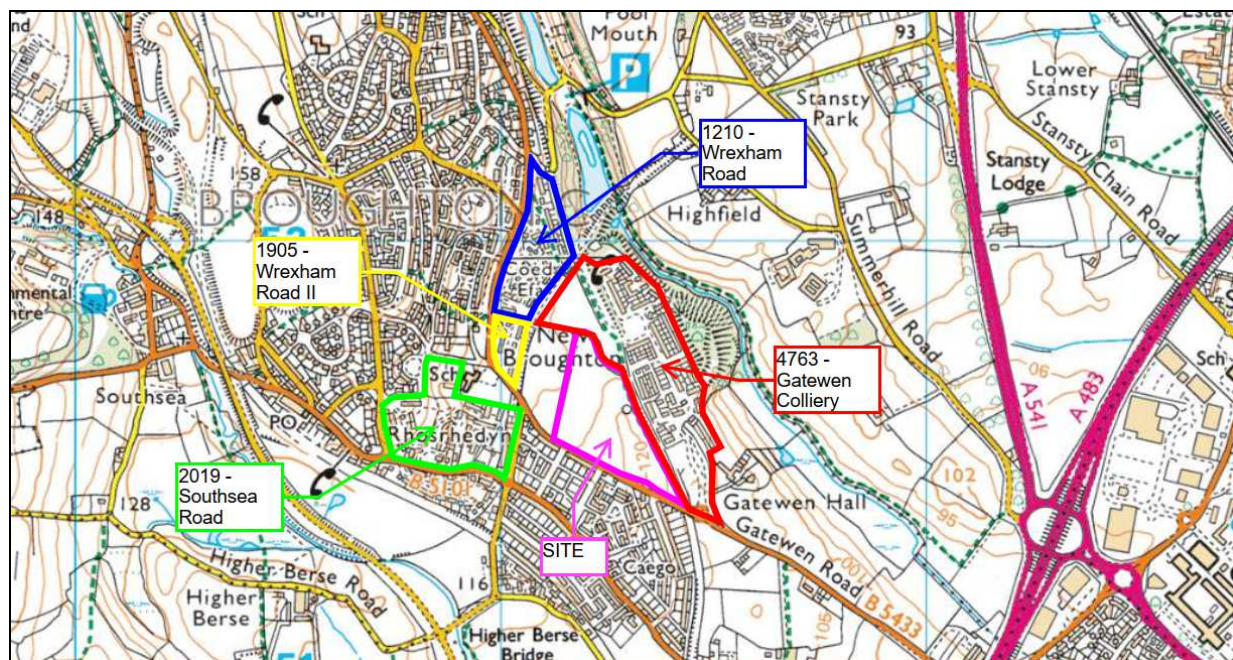


Figure 1: Showing approximate locations of sites with ground investigations in the local area, either undertaken or assessed by Coopers. Ordnance Survey Licence No. AL100005579

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6.2 **Investigations undertaken on the site**

No previous desk study or ground investigation report has been provided to Coopers as part of the pre-investigation pack. Intrusive investigations have been undertaken as part of assessments for drainage designs.

The developer provided a report which included trial pit logs as part of infiltration testing undertaken on the site by Earth Environmental & Geotechnical Ltd (EEG), in January 2019. The EEG investigation was undertaken for Scott Hughes Design Ltd as part of the drainage strategy assessment. The EEG works were provided within the below referenced correspondence, which included exploratory hole logs and infiltration test data, but no laboratory testing or other information relating to the ground conditions. Copies of the exploratory hole logs and test data are included in appendices for correlation with the findings of Coopers works.

Previous Report for the Site:

- Earth Environmental & Geotechnical (EEG) Ltd Correspondence “*Infiltration Testing Letter Report – Wrexham University, Gatewen Road*”, referenced A2813/19, dated 18th February 2019.

Summary of EEG report:

The investigation included a total of 5 No. mechanical trial pits to depths of between 1.9m to 2.3m in positions for the purposes of drainage assessments. The trial pits identified the presence of topsoil overlying glacial clays, with clayey sands or clayey sands and gravels identified in two positions. The upper clays were commonly described as soft, improving to firm with depth, although no testing was undertaken to support field descriptions. The findings were largely factual in nature, with the only items interpreted relating to infiltration rates for soakaway design.

6.3 **Investigations Undertaken Close to Site:**

Coopers Project No. 1210 – Wrexham Road (1995) - On behalf of Wimpey Holdings (now Taylor Wimpey):

- Coopers “Site Investigation Report”, referenced 951210/dtc/dob, dated 27 September 1995.

Summary Review:

The Coopers investigation included a basic desk study, with primary focus being geotechnical and structural design. The investigation included a total of 15 No. trial pits with subsequent geotechnical testing. The exploratory holes identified the presence of topsoil overlying glacial sands/gravels, with localised areas of glacial clay. Bedrock was encountered within several positions, the shallowest of which was underlying topsoil at 0.6m depth.

Coopers Project No. 1905 – Wrexham Road, Phase II (1998) - On behalf of Wimpey Homes (now Taylor Wimpey):

- I) Coopers “*Site Investigation Report*”, referenced 1905fr, dated 23 January 1998.
- II) Coopers “*Report on Soil Infiltration Tests*”, referenced 1905sir, dated 12 February 1998.

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i) 1905fr - Summary Review:

Interpretative desk study and intrusive investigation. Identified topsoil overlying gravelly sand with variable shallow bedrock. All soils were uncontaminated with regards to limited suites of testing (relative to then ICRC thresholds), all plots proposed for shallow reinforced strip foundations.

ii) 1905sir - Summary Review:

The report provided findings on the basis of 3 No. soil infiltration tests, which identified $1.15\text{--}6.58 \times 10^{-5}$ m/sec rates across the site.

Coopers Project No. 2019 – Southsea Road, Broughton (2000) - On behalf of David McLean Homes (now Taylor Wimpey):

- I) Coopers “*Site Investigation Report*”, referenced 2019fr1, dated 25 May 2000.
- II) Coopers “*Report on Soil Infiltration Tests*”, referenced 2019sir, dated 5 June 2001.

i) 2019fr - Summary Review:

Interpretative desk study and intrusive investigation for geotechnical appraisal. Identified topsoil overlying gravelly clays and sands, with localised shallow rockhead from 1.4m. Clays were typically firm, and sands loose to medium dense or medium dense. Localised soft to firm clays identified in places. No chemical testing or assessment of contaminated land. All plots proposed for shallow strip foundations.

ii) 2019sir - Summary Review:

Interpretative findings from infiltration testing. Identified granular strata to achieve rates of 3.9×10^{-4} m/sec to 3.07×10^{-5} m/sec although referenced that no testing of clays undertaken due to low infiltration rates.

Coopers Project No. 4763 – Gatewen Colliery (2010) - On behalf of Bloor Homes:

- I) Coopers “*Technical Summary Report*”, referenced 4763ts, dated 21 May 2010.

i) 4763ts - Summary Review:

Report included findings from Coopers supplemental investigation to previous reports provided on behalf of the vendor by third parties. Colliery included 2 No. mine shafts, operational between 1877 to 1932, after which was utilised as coal crushing/processing supplied by mineral railway running adjacent to Bellway Homes site. The ground investigation identified variable depths of colliery spoil in places >5.4m, deepest in the north east, overlying glacial clays with frequent lenses of glacial sand. Bedrock was identified at 5.6m to 11.8m consisting of mudstone or sandstone. Investigations identified contamination within madeground with elevated metals (arsenic, cadmium, copper, lead and zinc) and localised areas of petroleum range hydrocarbon contamination. Foundations varied by madeground depth, with proposals consisting of a combination of strip, trench fill, rafts, and designed foundations over vibro stone columns (some included rafts over vibro).

7.0 Site History

(Refer to Appendices 3 and 12)

The following site history has been compiled from various sources, these include a literature review, historical Ordnance Survey (OS) maps, and internet searches.

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A full copy of the historical maps generated by Groundsure are provided in Appendix 3.

Overlapping Historical Aerial Photography have been provided by Royal Commission on the Ancient and Historical Monuments of Wales, copies of which are included in Appendix 4.

Early History.

Archaeological Studies for the adjacent Gatewen Colliery development reference the early development in the local area being Gatewen Hall (Grade II Listed building), developed in the late 18th century, situated approximately 125m to the east of the site. Earlier records reference post medieval use of the land to north of the hall, including a reported Holy Well (Ffynnon Ddeuno Well) within a small building or chapel, subsequently covered with spoil heap. Archaeological assessments cast doubt on this, referencing the identification was made in 1910 and possibly misidentified a potential former lime kiln referenced on the 1899 Ordnance Survey map.

The Tithe maps of 1844 (National Library of Wales website – Figure 2) show the site to consist of parts of 7 No. fields, referenced as owned by Pierce and Goff, and occupied by Joseph Garner, the majority of the fields were referenced for arable use, one of which was specified as hay.



Figure 2: Extract of Tithe map of 1844 (National Library of Wales Website)

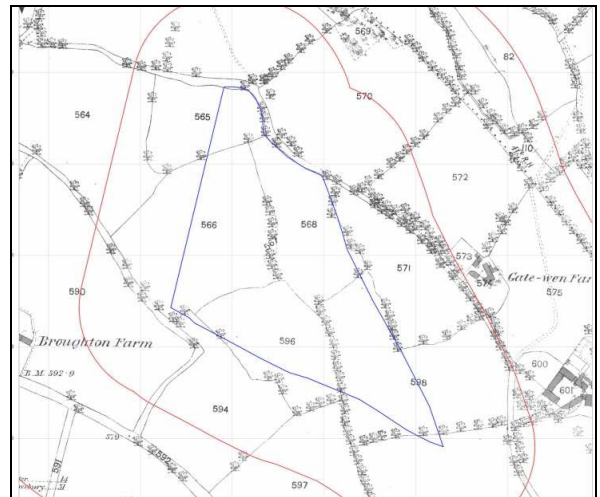


Figure 3: Extract of 1874 Ordnance Survey Map

1872/1874: The first edition Ordnance Survey maps (refer to Figure 3, above) recorded the site to consist of parts of 7 No. fields, segregated with tree lined hedges/fencing. The surrounding area comprised agricultural land and farm tracks/roads with Broughton Farm located approximately 125m to the west, Gatewen Farm 100m to the east, and Gatewen Hall located 125m to the east of the site.

1899: The majority of the field boundaries were removed, with a small area of woodland, and 2 No. small unreferenced buildings within the site (refer to Figure 4). Gatewen Colliery was established to the east of the site, with mineral railway running close to the eastern site boundary. Archaeological reports for the colliery reference the shaft was sunk in 1875 which continued to 1877 when the colliery opened. Gatewen Road was constructed to the south of the site, with cutting and filling relative to the site in the south east where the road bridged over the mineral railway.

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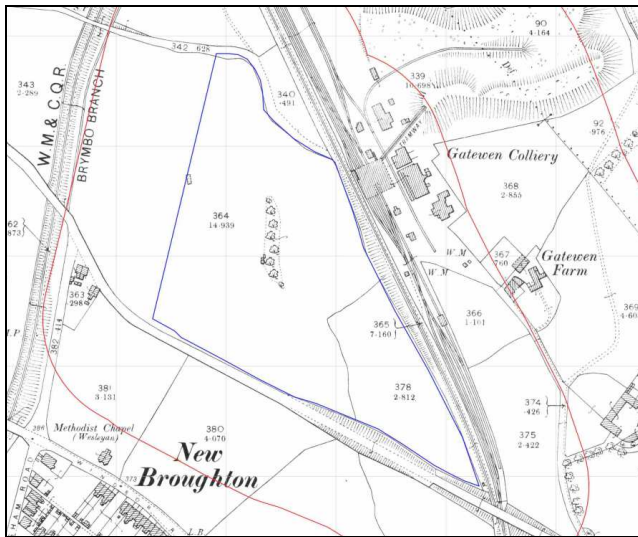


Figure 4: Extract of Tithe map of 1899 (National Library of Wales Website)

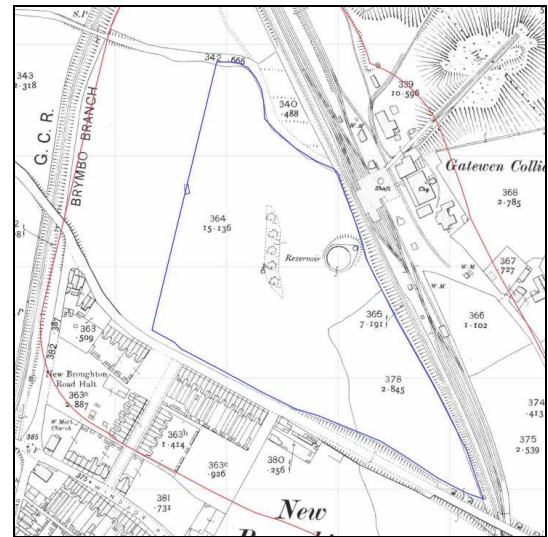


Figure 5: Extract of 1912 Ordnance Survey Map

1910: A referenced reservoir, circa 20m diameter, and associated wells/infrastructure was recorded in the eastern part of the site (refer to Figure 5). It is unknown if the reservoir was open or covered. The reservoir is conjectured to have been utilised for the mineral railway with associated steam engines which required large volumes of water for frequent refilling (refer to Figure 6). Terraced residential housing was constructed to the south of Gatewen Road, opposite to the site.

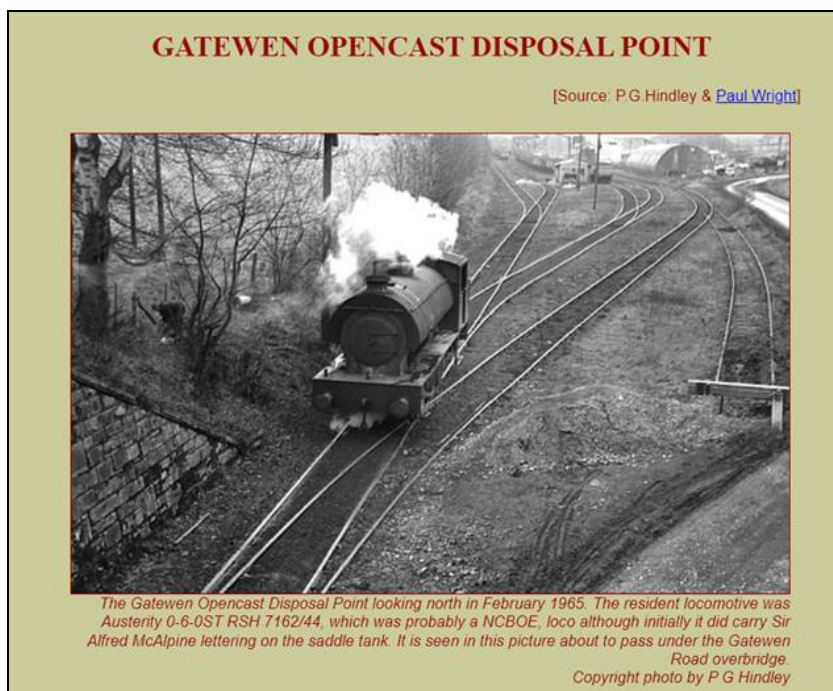


Figure 6: Image of steam engine on the Gatewen Colliery, taken from the bridge over the railway close to the south eastern corner of the site, with site visible to the left of the image. Photograph dated 1965

1939: The field boundaries were realigned to current positions, and the reservoir shown but not referenced. The adjacent Gatewen Colliery was referenced as disused with buildings, spoil heaps and railway sidings in place.

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1962-Present: The subsequent map editions show no substantial changes to the site.

By 1963 the former Gatewen colliery was referenced as a combination of Coal Crushing plant and transport training centre, with changes to the profile of the former colliery spoil mound. By 1994 the mineral railway adjacent to the eastern site boundary was referenced as dismantled. The former colliery was subsequently developed in phases by Bloor Homes from 2007.

The land to the south was recorded to have progressive areas of residential development from 1963 to 1994. The land to the west of the site was recorded as a sports ground by 1963 to present.

8.0 Hazardous Installations and Development Constraints

(Refer to Appendix 2 and Site Plan in Appendix 15)

8.1 Findings

The Environmental Data Reports (Appendix 2) details there are no significant referenced environmental permits or hazardous installations within 500m of the site. It is advisable to consult with the Local Authority Planning Department to confirm if any other limitations/restrictions apply.

Pollution Incidents: The Groundsure Report references 1 No. National Resources Wales recorded pollution incident within 500m of the site, relating to minor impact to land 373m north of the site in 2014. Given the location and nature of the incident this is not considered to have any significant impact to the proposed development.

Dangerous/Hazardous Sites: The Groundsure Report contained within Appendix 2, includes public records of hazardous installations. This referenced that within 500m of the site there are no recorded COMAH (Control of Major Accidents and Hazards), high pressure gas pipelines, regulated explosive sites, hazardous substance storage/use, or radioactive substance authorisations.

There is 1 No. current or former licensed industrial/pollutant site or activity (IPC, Part A1, A2/B) within 500m of the site, relating to a waste oil burner at a garage 206m south west of the site.

Discharge Consents: There is 1 No. recorded discharge consents within 500m of the site, relating to sewage discharge as sewer storm water overflow to the River Gwenfro 478m to the south west of the site.

Current Land Uses: The Groundsure Report identified within 500m of the site there are 10 No. recorded industrial sites:

- 4 No. are electrical substations (>50m from site).
- 2 No. sewage operations (referenced ppg, and pumping station).
- 2 No. vehicle repair/testing/servicing.
- 1 No. vehicle hire/rental.
- 1 No. distribution/haulage.

Conservation and Ecology Designations: The Groundsure Report details that within 500m of the site the following environmental designations are present:

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- 1 No. Sites of Special Scientific Interest (SSSI), relating to the Gatewen Marsh (219m north east).
- 2 No. areas of Designated Ancient Woodland, situated at least 169m from the site.

It is advisable to commission specialist ecological consultants to assess potential impacts of development in relation to conservation and ecology.

Hazardous Building Materials: As detailed within Coopers' site description (Section 5), at the time of the walkover there was 1 No. small building of unknown use, situated within the central part of the site, with surface features/wells associated with a former reservoir (built 1899-1910). The small building was of brick construction, built 1874-1899.

The age and nature of the former buildings on site are considered unlikely to have included asbestos within their buildings. Client supplied information included reference to a former asbestos cement pipe crossing the south eastern part of the site, which will require safe removal from site, following the Control of Asbestos Regulations (2012).

The presence of asbestos containing soils are further discussed in Section 16 (Contamination).

Live Utilities: Utilities plans have been provided indicating the presence of live services in the south eastern part of the site, including potable water and foul sewers.

8.2 Conclusions

Based on the findings of our review there are no significant hazardous installations or likely development limitations, although specialist surveys would be recommended in respect of ecology.

9.0 Landfill Sites and Infilled Ground

(Refer to Appendix 1 and 2)

9.1 Findings

According to the Groundsure Report (Appendix 2) and National Resources Wales website (Appendix 1) there are no recorded Historical Landfills situated within 500m of the site. There is 1 No. recorded waste exemption within 500m of the site, relating to sorting/processing of controlled drugs at a veterinary 371m south east of the site.

10.0 Geology, Hydrology & Hydrogeology

10.1 General

The following section is based upon desk study information only. For details of the findings of the ground investigation and ground conditions refer to Section 14. The following sources of information have been assessed:

- 1:10,000 scale British Geological Survey - Geological Map, National Grid Series, Sheet SJ 35 SW (Drift).

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- 1:50,000 scale online maps – British Geological Survey (BGS) website.
- Groundsure Report (Appendix 2).
- British Geological Survey, Technical Report WA/91/4 (1991) “*Applied Geological Mapping in the Wrexham Area: Geology and Land-use Planning*” and associated maps.

10.2 **Drift**

The geological maps record the majority of the site to be underlain by glacial till (glacial basal till), with fluvioglacial sands and gravels (glacial washout/fan deposit) in the western and south eastern part of the site (refer to Figure 7). The geological history describes the glacial advances and retreats resulted in variations and overlays of these deposits.

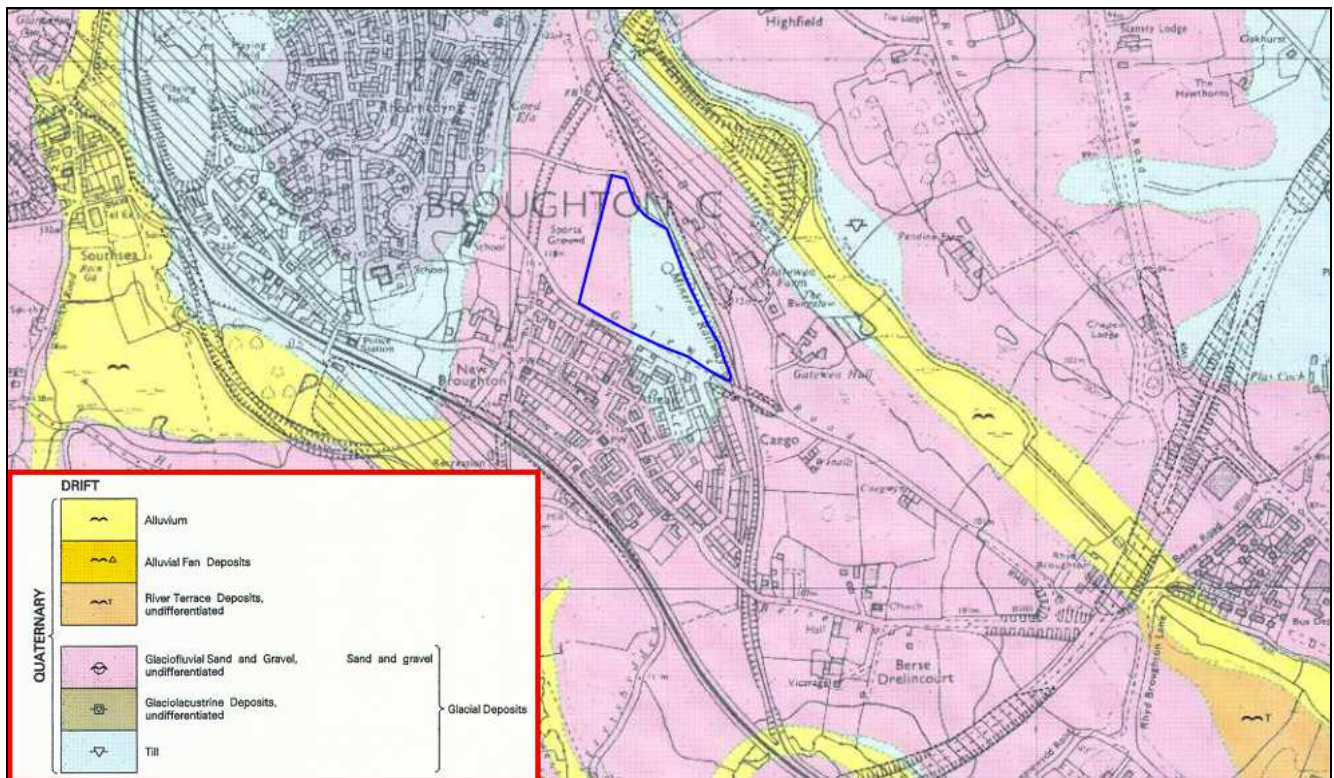


Figure 7: Extract of Geological Map SJ35SW (drift) with annotated approximate site boundary

The BGS Technical Report references drift to be approximately 5m below ground level in the west, to 15m below ground level in the east. The BGS website includes 5 No. boreholes drilled from surface to depths of up to 6.71m, referenced SJ35SW863-867, drilled in 1963. The boreholes identified primarily red-brown and/or grey sandy/stony clays with layers of sand and gravel.

10.3 **Bedrock**

Geological mapping records the bedrock underlying the majority of the site to be Pennine Lower Coal Measures – Mudstone, Siltstone and Sandstone of Carboniferous age (318-319 Ma). The eastern corner of the site is recorded as Pennine Middle Coal Measures of Carboniferous age (310-319 Ma). Within the south western part of the site the bedrock is recorded as Cefn Rock - Sandstone, which of 310-315 million years old. There is 1 No. deeper BGS borehole within the site. This was drilled below the Main Seam (Coal - depth circa 200m) from workings in Gatewen Colliery, which progressed to a depth of 152.4m below the Main Seam. The borehole logs includes the position of the borehole and the extent of workings of the main seam from Gatewen Colliery, relative to positions of the mines shafts (Figure 8).

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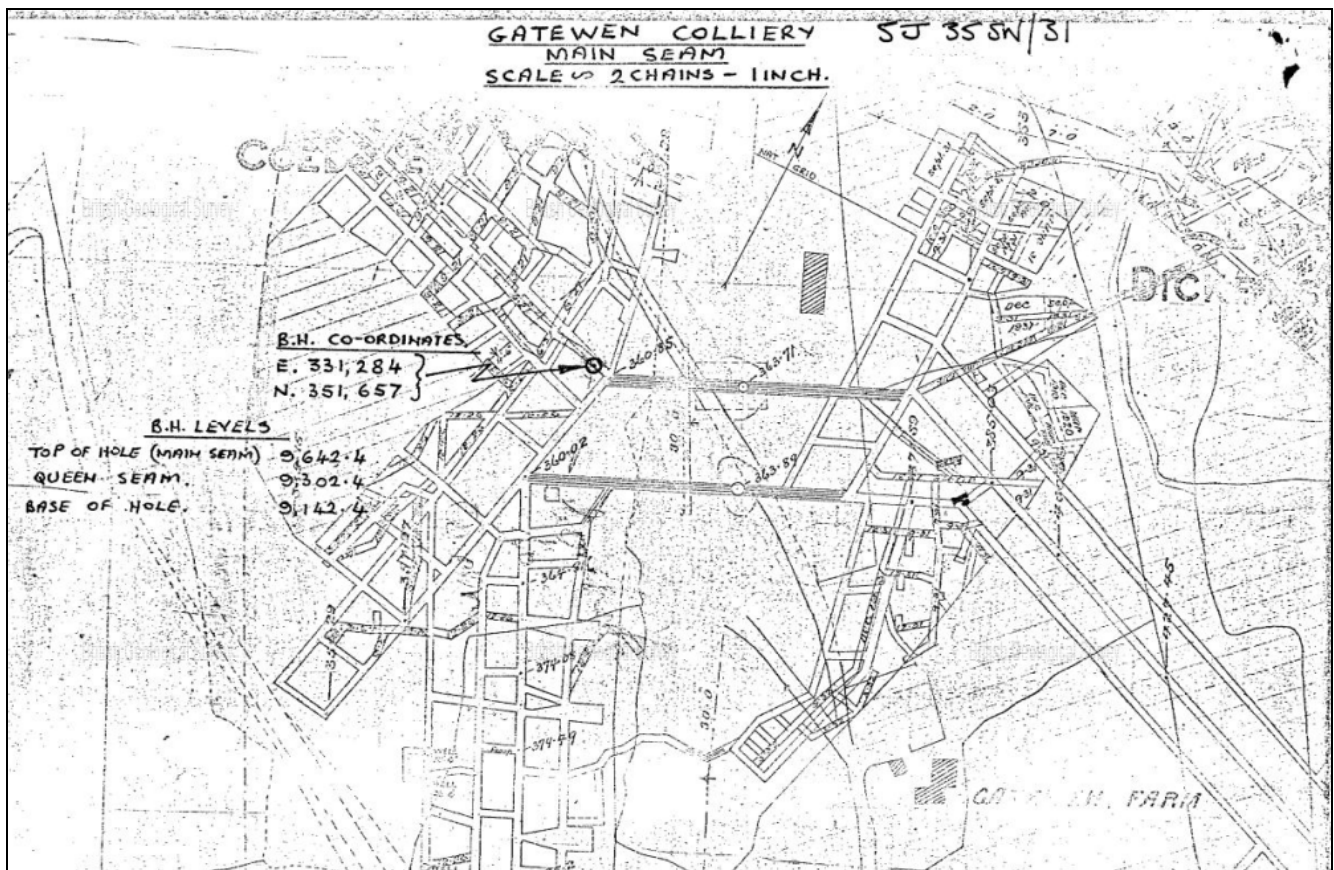


Figure 8: Extract of Geological Borehole Records, showing extent of workings from Main Seam at Gatewen Colliery

10.4 **Geological Faults**

The closest recorded geological fault is recorded approximately 25m east of the site, running north west/south east.

10.5 **Groundwater Vulnerability and Hydrogeology**

The drift geology across the majority of the site is glacial till, designated as a “Secondary Aquifer – Undifferentiated Layer.” This is described as *“assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.”*

The drift geology across on the western and south eastern corner of the site is designated as a “Secondary A Aquifer”, described as *“permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.”*

The bedrock geology is designated as a “Secondary A Aquifer”, as described previously.

There are no current groundwater abstraction licences on or within 500m of the site, and the site is not located within a Groundwater Source Protection Zone.

The Groundsure Report records 3 No. historical licensed groundwater abstractions within 2km of the site, all of which relate to wells at the former Carlsberg Tetley Brewing Company, 1.3 to 1.4km from the site.

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10.6 **Hydrology**

The closest surface water body to the site is located 221m to the north east of the site, consisting of an unnamed tributary of the River Gwenfro. The site is within the waterbody catchment of the River Gwenfro, which is a tributary to the Clywedog – Dee.

The Groundsure Report records 1 No. active surface water abstraction license within 2km of the site, relating to irrigation 704m to the south of the site. There are 4 No. historical licenses within 2km, relating to irrigation 704m to 1343m south of the site from River Gwenfro and tributaries.

10.7 **Flood Risk**

The site is not situated within a zone of potential flooding from rivers and seas, which would be designated as Zone A in accordance with NRW flood mapping and the proposed development. There are no recorded historical flood events, flood defences, or recorded flood storage areas referenced within 250m of the site.

Site specific assessments of flood risks are not part of the remit of this report and reference should be Scott Hughes report and any specialist advice is recommended to assess flood risks relative to the development proposals, where required.

10.8 **Mineral Safeguarding**

Where mineral resources are present the mineral planning authority may designate areas as Mineral Safeguarding Areas (MSA) and Mineral Consultation Areas (MCA). These are aimed to safeguard areas from unnecessary sterilization by non-mineral development. The BGS North East Wales Mineral Resources Map defines the site to overlay a “*Secondary Shallow Coal Resource*” with defined fluvioglacial sand and gravel deposits.

The BGS applied geological mapping defines areas of commercial resource potential in drift and bedrock. The bedrock resources map (Map 6) define the sandstone of Cefn Rock as feldspathic sandstones which are variable, in places of aggregate quality. Numerous former quarries are recorded to the north of the site (where bedrock also shallows close to surface). The sand and gravel resources map (Map 7) defines the areas of fluvioglacial sands and gravels are “potentially workable, generally exceeding 1m in thickness”. The mining activities – coal/metalliferous defines the site to have been subject to working of at least one to more than one coal seam.

Given the geological conditions, the site is not considered favourable for commercial mineral resources abstraction compared with local resources. Historical abstraction of coals have occurred previously therefore no further resource abstraction potential at shallower depths. The proposed development is therefore not considered as potentially sterilising mineral resources with no significant impact associated with the development.

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10.9 **Oil and Gas Production**

The Oil and Gas Authority website details the site is not situated within a region of licenses for future hydraulic fracturing (or fracking) of shales (primarily Bowland Shale Formation – within Carboniferous bedrock) for gasification is present. Whilst the site is within an area overlying Carboniferous bedrock, abstraction has been targeting these deposits at depths, therefore not likely to be proposed where close to subcrop. Coopers cannot comment on the reported safety, policy or

environmentally sustainability of these operations, although consider the potential for future drilling for exploration or abstraction wells close to the site to be relatively low given the context of the site and the geological conditions.

10.10 **Subsidence Hazards**

The Groundsure Report notes that the site is designated as very low risk, or negligible risk from collapsible ground, ground dissolution, shrinking and swelling clays, compressible ground and running sands. The eastern periphery of the site and adjacent ground is referenced as low risk of landslides, relating to a small section of sloping ground to the footpath and residential housing. As outlined in the site description the slope showed no evidence of failure, with vegetation/trees and unless loaded by raising development levels would not be considered as a potential significant risk of landslides.

11.0 Environmental, Archaeological, Ecological and Conservation Issues

(Refer to Appendix 1 and 2)

11.1 **General**

The determination of important archaeological, ecological or conservation constraints would require assessments by suitably qualified persons and are considered beyond the scope for appraisal within this report.

As outlined in Section 8.0, the Groundsure Report (Appendix 2) details sensitive conservation and ecological designations within 1km of the site, which are:

- 1 No. Sites of Special Scientific Interest (SSSI), relating to the Gatewen Marsh (219m north east).
- 2 No. areas of Designated Ancient Woodland, situated at least 169m from the site.

Archaeological reports for the adjacent developer of the former Gatewen Colliery highlighted local sites of interest, including Gatewen Hall, situated approximately 130m to the east of the site, and the former colliery. The site history (Section 7.0) highlights the presence of former buildings on site, including a former reservoir, likely to be associated with the former mineral railway to the east of the site.

11.2 **Conclusions**

Based on the findings of our desk study, we do not anticipate that the site is likely to be significantly affected by environmental, archaeological, ecological, or conservation issues. It is advisable to contact the Local Authority Planning Department regarding any limitations or restrictions associated with the proposed development and any further requirements for surveys/reports by specialists in these fields.

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12.0 Mining and Brine Extraction

(Refer to Appendix 2 and 5)

12.1 Brine Subsidence

The Groundsure Report (Appendix 2) defines the site as being outside of a zone of historical brine abstraction, with no soluble rocks identified. The site is therefore not at risk of brine subsidence.

12.2 Coal Mining – Consultation Areas and Risk Designation

According to the Groundsure Report (Appendix 2) the site is within a coal mining area, where coal mining reports would be required. Coopers commissioned a CON29M Coal Mining report from The Coal Authority (Appendix 5). The report references the site is underlain by mining of 6 No. coal seams at depths of 100m to 230m below ground level, last worked in 1932. The below summary details that the site is not within a high-risk development area, therefore no detailed mining assessments are required.

The Coal Authority is a statutory consultee on planning applications within defined coal mining areas. Specific advice on the requirements for these areas are defined within the Coal Authority publication “*Risk Based Approach to Development Management Guidance for Developers*” Version 4, 2017. The guide details the areas underlain by historical workings are defined as a consultation area. The consultation area is split into low risk and high risk areas.

The Coal Authority define a Development Low Risk Area as “*whilst coal mining has taken place in this area, it was at such depth not to pose a public safety or ground stability risk to new development.*” The Coal Authority confirm that where defined as a low risk the requirements are: “*If your proposed development is within the Development Low Risk Area there is no need for you to submit any coal mining information with your planning application and The Coal Authority will not be consulted by the LPA. The LPA will include our Standing Advice as an informative note with the decision notice.*”

High Risk Development Areas are defined by the Coal Authority as “*Contains specific recorded coal mining legacy risks which pose a public safety and/or ground instability risk to the surface.*” The definition of the risks which would be designated as a high risk are as follows:

- Mine entries;
- Shallow coal workings (recorded and probable);
- Workable coal seam outcrops;
- Mine gas sites and areas;
- Recorded coal mining related hazards;
- Geological features (fissures and break lines);
- Former surface mining sites/high wall (sometimes using historic opencast extraction methods).

Coopers ordered a Coal Authority CON29M Non-Residential Mining Report, referenced 51002544925001, dated 17 May 2021 (Appendix 5), which references the site is underlain by deep workings, with none of the above high risk items highlighted, therefore considered likely to be within a low risk area where detailed mining assessments are not required.

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Irrespective of this designation an initial assessment has been undertaken to confirm there are no significant further risks disclosed.

12.3 **Coal Mining – Initial Mining Risk Assessment.**

As highlighted above the Coopers site investigation boundary is defined by the Coal Authority as not being within a high risk development area and therefore not requiring a mining risk assessment. The following is a data appraisal and summary of the available data from a desk based assessment to confirm the risks have been suitably considered. These demonstrate the site to be outside of areas of potential significant risks from historical coal mining with no further investigation or treatment required.

Mine Entries: The Coal Authority mining report details there are no recorded mine entries within 20m of the site. The former Gatewen Colliery was located to the immediate east of the site which included 2 No. mine shafts and a addit (fan drift), all of which were located and treated prior to development by Bloor Homes (with Coopers providing engineering consultancy). The likelihood of unrecorded mine shafts on site are relatively low, given the absence of shallow coal seams (discussed below). The risks of mine entries to the proposed development is therefore negligible.

Worked shallow seams and outcrops: The mining report details that the site is underlain by 6 No. worked seams, at depths of 100m to 230m, last worked in 1935, with no referenced potential for shallow mine workings. The BGS applied geological mapping shows the closest recorded subcrop of coal approximately 575m to the west of the site, dipping to east. Whilst dip angle is not recorded on the maps, inferred depths from sections would be circa 22°. The depths of worked seams within the area is complicated by a series of geological faults, the closest of which is recorded to terminate within the south eastern part of the site.

The ground investigation (Section 14) has disclosed drift to be >4.45m, with bedrock anticipated to be at 5m to the west to 15m in the east. As worked seams at least 100m below existing ground level, there will be significant rock cover (min. 85m), limiting the propagation of voids from worked seams to reach the surface. As highlighted in The Coal Authority report the age of workings (89 years prior) would also mean any collapse of workings should have occurred. The potential influence to the surface from below ground worked seams is therefore negligible (given the depth and age).

Mine Gas Sites/Areas: Areas of open workings can pose a high risk of mine gas release which pose a risk to life, particularly where gases enter confined spaces such as buildings or trenches. The primary risks from mine gases are posed where accumulated in open workings which then migrate where displaced (commonly through either mine treatment or flooding after abandonment) or pathways created by development (e.g. vibro stone columns on to treated mine workings). Given the depth and age of workings these are likely to have been flooded with no proposals to treat or create pathways incepting the mine workings. The Coal Authority mining report confirms there are no records of mine gas emissions requiring action for the site. The site is therefore considered as at negligible risk from mine gas emissions.

Recorded Coal Mining Hazards: There are no referenced further coal mining hazards based upon the recorded information from the coal authority and desk study.

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Geological Features (fissures and break lines): The geological maps record the presence of a geological fault terminating into the south eastern part of the site, with a further fault to the east of the site within the former colliery. Faults or fissures can be a consideration for any foundation construction. The primary risks associated with coal mining are associated with mining induced fault reactivation (where mining of coal up against the fault and subsequent abandonment and flooding causes shallow displacement). Fault reactivation can cause substantial surface movement and damage to buildings. Records of mining induced fault reactivation in the UK (Donnelly, 2007) states there are no known or recorded cases of mining induced fault reactivation in the North Wales coal field, although the author cautions that these may have occurred and been misidentified or attributed to other causes. The Coal Mining report references they are not aware of any damage due to geological faults or other lines of weakness affected by coal mining. The site is therefore considered to be at negligible risk from coal mining induced fault reactivation.

Former surface mining sites/high wall (sometimes using historic opencast extraction methods): The depth to coal mine seams and records from the adjacent colliery suggest that the site would not have been subject to open cast mining and therefore considered as unaffected.

12.4 **Non-Coal Mining**

The Groundsure Report details the site is within an area where potential bedded iron ore (e.g. haematite) may have been historically mined. This is referenced as “*Localised small scale underground mining may have occurred. Potential for difficult ground conditions are unlikely or localised and are at a level where they need not be considered.*” The BGS technical report highlights the closest related metalliferous mining is within the area of Minera, approximately 4.5km to the west of the site, with mining of veins of lead and subordinate zinc and copper. The geological conditions present do not indicate the site or local area to be likely to have been subject to historical iron ore extraction and therefore considered as unaffected.

13.0 Radon

(Refer to Appendix 2)

The Groundsure Report (Appendix 2) designates the site as within an area where 10-30% of properties are above the radon action level. This is designated as a level where Full Radon protection measures are required for new buildings. As detailed in BR211 (2015), assessments and testing for radon ingress is only possible after occupation, therefore it is not possible to undertake on site monitoring of radon prior to construction.

Radon is a naturally occurring radioactive gas with no visual or olfactory detection potential. Radon has no significant acute risk, however at higher concentrations the lifetime lung cancer risk is significantly increased. It is estimated that the annual number of lung cancer deaths in the UK as a result of high radon exposure from the ground is 1,100 persons per annum (*Public Heath Wales website*).

In general the presence of other forms of gases would supersede those of basic radon precaution measures from a design perspective, although this is subject to much current debate (particularly on the mitigation from acute risks at low mortality rates against chronic risks of much higher numbers of fatalities).

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The design and verification of radon protection measures are detailed within BR211 (2015), which covers a range of floor slab construction and radon risks. For full radon areas the primary form of protection is through installation of a proprietary radon membrane within the floor slab construction, with secondary protection formed with a sub floor ventilation layer.

The membrane is recommended to consist of a min. 1200 gauge virgin polymer LDPE (although consideration is recommended on the use of higher specifications due to the membrane having low puncture resistance and difficulties in installation without significant amount of damage/defects). A typical construction detail for full radon protection measures for the proposed floor slab construction is provided in Appendix 15.

The verification approaches to installation of radon protection are more critical than that of other gases such as methane and carbon dioxide (BS8485), due to the relatively low amount of radon ingress required to exceed the action thresholds of 200Bq/m³. Traditionally NHBC have not typically required verification of the installation of radon barriers, although outline proposals for revisions to BRE 211 are reported to further emphasize the importance of verification.

The levels of radon in residential buildings can only be identified after occupation and Public Health Wales advise that all new dwellings should be subject to a radon test within the first year of occupation. This is however not a requirement under Building Regulations and can be difficult to implement where ownership of the properties is transferred to the residents.

The recommendations for radon mitigation measures are discussed in Section 17, with proposals for verification provided in Section 18.

14.0 Ground Investigation

(Refer to Appendices 6 to 8, 11, 12 and 15).

14.1 Methodology

The ground investigation by Coopers was designed to disclose the typical ground conditions across the site and target potential abnormal ground conditions. The investigation included a combination of trial pits, infiltration test pits, hand dug pits and small diameter boreholes, designed to identify the ground conditions and features at varying depths.

The investigation required boreholes for the purposes of installation of monitoring wells along with in situ testing for geotechnical appraisals. These were supplemented by additional excavations for the purposes of delineating ground conditions.

There were no significant limitations to the development, other than a safe stand off from positions of live services and the former reservoir, which was not known if covered or filled.

Coopers undertook the following:

- 5 No. small diameter boreholes (referenced WS01 to WS05) up to 4.45m in depth.
- 15 No. trial pits (referenced TP101 to TP115) up to 2.9m in depth.
- 4 No. infiltration test pits (referenced ITP1 to ITP4) up to 2.55m in depth.
- 2 No. hand dug pits (referenced HDP1 and HDP2) up to 0.5m in depth.

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All exploratory hole positions are shown on Coopers Drawing No. 7791/01 in Appendix 15, with copies of exploratory hole logs contained in Appendix 6 to 8.

14.2 **In-situ Testing**

The boreholes by Coopers included Standard Penetration Tests (SPTs) at 1m intervals within the upper 4m. These works provided specific geotechnical information for use in the foundation appraisal, contained in Section 23. Hand shear vane tests were undertaken on recovered cohesive strata, although in places was limited by gravelly clays or friable sandy clays.

14.3 **Monitoring Wells**

Monitoring wells were installed in the small diameter boreholes to assess potential hazardous ground gases. Details of the monitoring wells are provided on the boreholes logs and discussed in Section 15.7.

14.4 **Sampling Strategy**

Coopers investigation and sampling looked to address the key considerations for the proposed site development with consideration of the previous uses of the site. This included coverage and targeting to identify typical ground conditions and potential variations with likely abnormal conditions. Coopers Drawing No. 7791/01 in Appendix 15 includes an overlay of the historical buildings and features, in conjunction with the exploratory holes by Coopers.

Types of laboratory suites by Coopers were scheduled for chemical testing based upon the likely types of contaminants in accordance with series of BS ISO 18400 (2017) “*Soil Quality – Sampling*” and visual/olfactory observations during the exploratory holes. The suites of testing by Coopers were reflective of the conceptual model and ground condition. The initial conceptual model and basis of the sampling strategy are discussed in further detail in Section 16 of this report.

Chemical and Geotechnical laboratory testing was commissioned by Coopers for testing by Derwentside Environmental Testing Services (DETS), and Murray Rix to define the typical properties of the strata.

Copies of the chemical test results are provided in Appendix 11 and the geotechnical testing in Appendix 12.

15.0 Ground Conditions Encountered

(Refer to Appendices 6 to 8 and 15)

15.1 **General**

The investigation by Coopers was a targeted-adaptive approach, where positions were situated to target former field boundaries or other features to identify the potential variations and where variable ground conditions identified these were subsequently delineated. Assumptions on average thickness of strata based upon exploratory holes numbers is therefore going to introduce a statistical bias due to the targeted investigation strategy.

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15.2 **Hardstanding, Foundations and Services**

No surface hardstanding was identified within the site investigation exploratory holes.

A small unknown dilapidated brick structure was located in the central part of the site, due to the nature of the building no trial excavations were undertaken alongside the building to determine the nature of the remnant substructures.

The site walkover identified the presence of brick walls at surface associated with a former reservoir with rough ground and trees over the former structure. Partially filled wells/chambers were also recorded adjacent to the reservoir. From review of the historical Ordnance Survey maps. It was unclear if the reservoir was covered or open and then subsequently filled. The reservoir was considered likely to have been for supply of water for steam locomotives on the former mineral railway to the colliery to the east of the site. Given the use it is likely to have been filled rather than covered although this would require confirmation as this maybe susceptible to future collapse and any requirements for filling/treatment. Historical aerial photography (Appendix 4) was ordered from Royal Commission of Ancient and Historical Monuments of Wales, to determine if the reservoir was visible at surface. The area was largely tree covered dating back to at least the 1950's and not clear from the images. It is recommended to further investigate this reservoir to determine if subfloor voids are present, either through intrusive or non-intrusive methods. Subject to the findings of the investigation the wells/reservoir may require treatment but should not result in development offsets or impacts to the surrounding development proposals. Alternative enquiries to local history or railway enthusiasts may enable further assessments of the nature of steam engine reservoirs and the potential construction.

15.3 **Topsoil**

The topsoil was identified across the site, typically of good textural quality, at depths between 0.2m to 0.3m, average of 0.24m. The majority of the topsoil displayed no evidence of reworking, although localised areas were identified to have brick fragments.

15.4 **Made ground**

Made ground was generally absent, with the exception of the area of the covered reservoir. Investigation of the reservoir was limited to hand dug pits, but proved the presence of ash and clinker, with brick, glass, metal and timber to >0.5m depth.

15.5 **Natural Drift Strata**

Glacial Clays and Fluvioglacial Sands and Gravels.

The geological maps define the presence of fluvioglacial sands and gravels over the majority of the site, with glacial till (clay) in the central section. The ground investigations identified the ground conditions to be more variable with layers of firm, firm to stiff or stiff clay with typically loose to medium dense sands and sands and gravels. Many of the strata were identified to have moderate cobble contents, typical of the region.

15.6 **Bedrock**

During the site investigation no bedrock was encountered. The bedrock is conjectured to be circa 5m depth in the west to 15m in east, based upon BGS maps and investigations close to the site.

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15.7 **Groundwater**

No groundwater was encountered within exploratory hole logs to depths of 4.45m. During winter months or following prolonged rain localised perched waters are likely to be encountered above layers of lower permeability strata, but should be easily dealt with via conventional sump pumping. If deeper excavations for sewer designs are needed then further investigations are recommended to determine the ground water conditions at depth.

16.0 **Contamination Assessments**

(Refer to Appendices 1 to 4, 6 to 8, 11, 13 and 15)

16.1 **General**

Coopers were commissioned to undertake an intrusive investigation with assessment of potential contamination. The investigation was designed to target the potential sources of contaminants and delineate, where possible, the extent.

The site is proposed for residential development by Bellway Homes (North West), comprising of 112 No. residential plots, of which 88 No. are traditional residential properties with the remaining plots within 2 No. apartment blocks. The housing includes a combination of traditional detached, semi-detached and 3-6 block mews residential houses with associated roads, private driveways, garages, gardens and landscaping. The proposed development layout is shown on APD Drawing “Planning Layout”, referenced BHNW130. PL01, revision A, dated 24 September 2021. An extract of which is overlain on Coopers Drawing No. 7791/Fdz, within Appendix 15. It is also assumed that all materials and workmanship will comply with the Building Regulations and the NHBC Standards.

This is an appraisal of the issues identified to date regarding contamination with respect to future residents occupying the site, contractors working on site, the surrounding residents/workers/members of the public and the surrounding environment.

Details regarding the legislation which sets the framework for contaminated land assessment have been included within Appendix 13.

16.2 **Summary of Initial Conceptual Site Model – Sources/Exposure Pathways/Receptors.**

The initial conceptual model has been provided based upon the current use of the site, disclosed during the site walkover (refer to Section 5) and former use of the site based upon desk study data (refer to Section 7).

The site was historically agricultural fields, with subsequent changes to field boundaries, a small building of unknown nature was recorded in the central part of the site by 1899, prior to construction of a reservoir and well/chamber in the eastern part of the site by 1910, conjectured to be used for water supply for steam engines on the adjacent mineral railway.

As discussed below the former agricultural use and absence of significant reworking of soils across the site would be defined as a very low risk in relation to sources of contamination, although the proposed end use (residential) is highly vulnerable to chronic exposure, primarily through exposure to soils with the growing medium of gardens.

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Potential Source of Contaminants – General madeground containing inorganic and PAH compounds.

Madeground was generally absent with the exception of the areas around the former reservoir which was identified as filled with very sandy gravels of ash/clinker, charcoal, glass, fragmented brick, metals and timber. The materials included partially combusted furnace deposits (ash, clinker, charcoal). The partial combustion process will commonly result in an increase in inorganic (metals) and PAH compounds. Elevated concentrations of these compounds are relatively widespread which commonly provide risks to human health from chronic exposure. Subject to the types of contaminants and their source, these contaminants will commonly be of low mobility with respect to risks to controlled waters.

Potential Source of Contaminants – Petroleum Range Hydrocarbons/Volatile Contaminants

On agricultural sites the areas of the farmyards commonly contained fuel storage for farm machinery where leaks of spillages were relatively common. Oils and lubricants for plant/machinery repairs can also commonly result in localised spills or releases in the shallow soil local to point of use. Once released into the soils these contaminants will be mobile and follow complex pathways with groundwater movements. These contaminants will commonly pose risks to human health from multiple exposure pathways, including inhalation of vapours/dusts, dermal contact with impacted soils and secondary ingestion (via hand to mouth or vegetable growth). The high mobility of these contaminants can pose risks to controlled waters where pathways exist to reach aquifers or perched groundwater/water courses.

The site was agricultural fields with no farmyard and recently used as paddocks for horse grazing. The potential presence of fuels or volatile contaminants are therefore considered relatively low.

Potential Source of Contaminants – Asbestos Fibres or Asbestos Containing Materials (ACMs).

Asbestos is listed as a common type of contaminant in all historical DoE industrial profiles, and should be assumed as present in any buildings constructed prior to the ban on use in 1999. The previous use as agricultural land, with a former reservoir, well and unknown former building. The buildings and use pre-dated peak use of asbestos in the UK (1950's-1970's). The developer supplied information indicating the presence of a disused asbestos cement water pipeline in the south eastern part of the site, the location of which is overlain on Coopers Site Plan, Drawing No. 7791/01 in Appendix 15. Subject to the condition of the pipeline and methods of construction this may have resulted in debris or fibres in local proximity to the pipeline.

The infill of the reservoir contained fragments of brick and glass, indicating materials included debris from former buildings of unknown provenance and age. These materials can commonly contain asbestos fibres or debris, which may not be visible other than under microscope examination.

The primary risks posed by asbestos are from inhalation during disturbance of soils containing asbestos, although secondary inhalation pathways from dermal/contact with soils can occur, particularly where soils are brought into homes on shoes or clothes, contributing to the indoor dusts.

Potential Source of Contaminants – Pesticides and Herbicides.

The site has been in recent use as grazing/paddocks for horses, observed by Coopers from at least 2009, with historical use as agricultural fields from at least 1844. Tithe maps reference the use of the fields as arable in 1844, including hay fields. The post mechanisation of farming practices would likely have resulted in the site use as pastoral, given the size of the site, and subsequent mechanisation of arable farming practices. The use of herbicides and pesticides for pastoral land was not common place, primary activities involved with nitrification (e.g. muck spreading). Whilst there is a low probability of the presence herbicides and pesticides these will commonly require chemical testing to confirm if present and the potential risks to human health and the surrounding environment.

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Pathway of Mobile Contaminants.

The presence of mixed cohesive and granular strata without a shallow water table would allow vertical and horizontal migration of mobile or leachable contaminants. Where present these can pose risks to aquifers, perched groundwater and surface waters/water courses.

Receptors – Human Health.

The primary human receptors are assumed to be the future residents with exposure to contaminants within gardens or properties through inhalation (vapours or dusts), dermal (soil contact), or ingestion (via hand to mouth or particles adhered to vegetable growth). Other common human health receptors can be contractors on site, adjacent residents, utilities maintenance workers and landscape gardeners. Whilst it is difficult to account for non-conventional uses of the site the likely exposure of these key receptors is considered in the context of the contamination findings in subsequent sections.

Receptors – Controlled Waters.

Discussions on the geological, hydrological and hydrogeological context of the site are provided in Section 10 of this report.

The primary controlled water receptors are surface waters, consisting of an unnamed tributary to the River Gwenfro, located 221m to the north east of the site. The site is within the waterbody catchment of the River Gwenfro, which is a tributary to the Clywedog – Dee.

The drift geology is a combination of Secondary Aquifer – Undifferentiated and Secondary A Aquifer reflective of the presence of glacial till and fluvioglacial sand and gravels, respectively. The bedrock geology is recorded as a Secondary A Aquifer. There are no current groundwater abstraction licences on or within 500m of the site, and the site is not located within a Groundwater Source Protection Zone. The Groundsure Report records 3 No. historical licensed groundwater abstractions within 2km of the site, all of which relate to wells at the former Carlsberg Tetley Brewing Company, 1.3 to 1.4km from the site.

16.3 **Investigation Strategy and Sampling Protocols**

The ground investigation was designed to get a general coverage across the site, and target specific areas to address local variations. The targeted positions were:

- Areas of former hedges.
- Areas of filled reservoir.

The investigation was not significantly limited, other than safe standoff from live services, with methods of investigation within the former reservoir limited to hand dug pits, as this was not known if covered and filled, or only filled.

The investigation included a combination of mechanical excavated trial pits (revealing a wider area of the shallow ground conditions, aiding assessment of built structures and lateral extent of shallow features), infiltration test pits (to assess sustainable drainage strategy), and small diameter boreholes (assisting in geotechnical data and shallow ground conditions, with monitoring wells for detection of hazardous ground gases). The following total number of exploratory holes were undertaken by Coopers:

- 5 No. small diameter boreholes (referenced WS01 to WS05) up to 4.45m in depth.
- 15 No. trial pits (referenced TP101 to TP115) up to 2.9m in depth.
- 4 No. infiltration test pits (referenced ITP1 to ITP4) up to 2.55m in depth.
- 2 No. hand dug pits (referenced HDP1 and HDP2) up to 0.5m in depth.

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Based upon the initial conceptual model and findings from the exploratory holes, Coopers scheduled a total of 31 No. samples for chemical testing by DETS. The primary focus of the testing was on the shallow topsoil (23 No. samples) and limited areas of made ground (2 No. samples) due to the potential for reworking and introduction of inorganic and PAH compounds along with asbestos fibres/debris. Smaller numbers of samples were tested for additional suites of testing based upon the initial conceptual model, along with testing of natural strata. The following sample numbers were subject to chemical testing suites:

- 18 No. soil samples for standard inorganics, PAH-16, pH, TOC, and sulphates).
- 20 No. soil samples for asbestos identification.
- 5 No. samples for TPH (CWG suite with aliphatic and aromatic banding by carbon range).
- 2 No. samples for VOC and SVOC.
- 2 No. samples for pesticide/herbicide screen suite.

Samples were taken on the day in appropriate containers for laboratory testing and stored within cool boxes, for return to refrigerators for cold storage prior to issue to the laboratory within 5 days to ensure samples were appropriate for the forms of chemical testing and not listed as deviating by the laboratory.

16.4 **Contamination Results – Initial Assessment Against Screening Values**

The laboratory testing was scheduled in batches for accredited analysis by DETS. The results of the testing are provided within the following laboratory certificates, contained in Appendix 11:

- EMT Test Report No. 21/11205, dated 7 June 2021.
- EMT Test Report No. 21/11610, dated 11 June 2021.

Samples were screened against available generic screening values for residential gardens with plant uptake, contained in Appendix 13 with associated explanation sheets. The results of which are discussed in subsequent sections.

Inorganic and PAH compounds

No elevated contaminants were identified in any of the samples in relation to Tier 1 thresholds.

Asbestos Containing Soils (ACS) and Asbestos Containing Materials (ACM)

No asbestos fibres, debris or ACM identified within any of the samples submitted for chemical testing.

Petroleum Range Hydrocarbons

No elevated contaminants were identified in any of the samples in relation to Tier 1 thresholds.

VOCs and SVOCs

No detected concentrations above laboratory limits of detection.

Herbicides/Pesticides

No detected concentrations above laboratory limits of detection.

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Groundwater Sampling and Results

No groundwater was identified within the ground investigation and therefore no waters samples were taken for laboratory testing. As outlined above, no contaminants have been identified within soils, which combined with the conceptual model was considered sufficient not to require any further analysis of leachate potential. The results of the laboratory testing confirm the site is not considered to pose a risk to controlled waters.

16.5 **Contamination Assessment – Summary and Further Actions.**

As detailed above, no contamination has been identified within the site, therefore no further detailed assessments or remediation is required for the proposed residential gardens. The proposed development will include regrading of site levels as part of a proposed earthworks. Initial cut and fill analysis by Coopers indicates there will be a surplus of topsoil and subsoil on the site, therefore no further proposals to import soils for the development.

The previously referenced redundant asbestos cement water pipeline within the south eastern part of the site should be removed by experienced, and trained personnel, following guidance from the Health and Safety Executive (HSE). The works should be recorded and verified and be compliant with the following

- Control of Asbestos Regulations, 2012.
- Health and Safety at Work Act, 1974.
- Construction (Design and Management) Regulations, 2015.

Following pipe removal Coopers recommend the soils in the position of the pipeline should be tested to determine if residual fibres/debris are present and if any further remediation is required.

In the event that any suspected contaminated soils or previously undisclosed sources of contaminants be identified during earthworks or development these will require further assessment and reporting to the Local Authority, prior to any remedial actions (if required).

The proposed cut and fill operations on the site will include reuse of soils on the site of origin. To ensure the works are not considered as an unapproved deposition of waste it is recommended that the process of reuse of soils follows the CL:AIRE: Definition of Waste - Code of Practice (DoW-CoP) with prior consultation with National Resources Wales and Local Authority and associated Qualified Person registration with CL:AIRE.

16.6 **Further Works**

The following further works are recommended to satisfy the risks associated with contaminants identified within the site:

- Submit site investigation report for local authority and NHBC approval.
- Undertake testing following removal of asbestos cement pipeline.
- Registration of intention for reuse of soils on site following CL:AIRE: DoW-CoP.

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17.0 Initial Ground Gas Assessment

Refer to Appendices 1 to 3, 5 to 8, 10, 11 and 15.

17.1 General

All information and advice regarding requirements for gas precaution measures are considered to be provisional until approval from statutory bodies has been granted. The assessment within this report details there are no significant potential sources of hazardous ground gases with the potential to impact the development, with the exception of radon. As detailed below gas monitoring is ongoing at the time of production, the findings of this assessment are therefore considered as for initial appraisal only and should be finalised following completion of the proposed monitoring.

The approaches to ground gas investigations and assessments of risks are detailed within the following British Standards:

- BS 8485:2015+A1:2019 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.*'
- BS 8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs).*'

The British Standards also refer to further guidance by CIRIA and NHBC, relating to assessments of gas risks, particularly CIRIA C665: '*Assessing risks posed by hazardous ground gases to buildings*' and NHBC Report No. 10627-R01 (04) '*Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide Are Present.*' It should be noted that the characteristic design models within the NHBC report assumes all properties have a pre-cast suspended slab. We have been advised by the report authors that for other types of slab construction reference should be made to the design and assessment criteria within CIRIA C665.

The ingress of hazardous ground gases into properties can occur through a variety of means, as summarised within British Standards BS8485 and illustrated within Figure 9 below.

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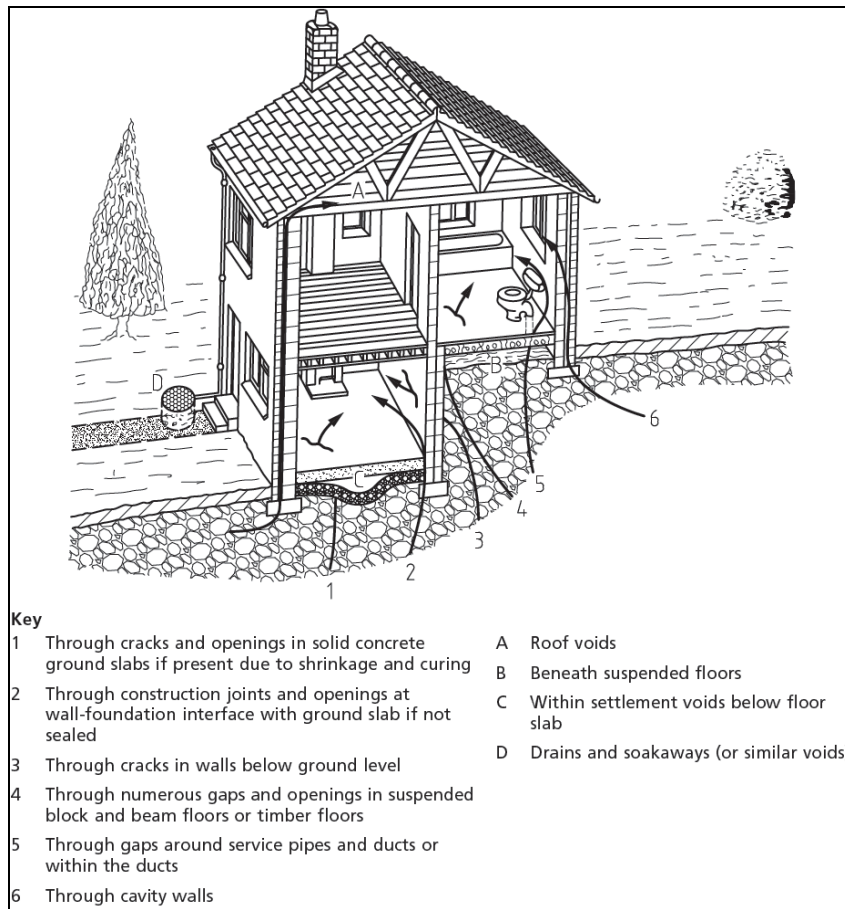


Figure 9: Potential pathways for hazardous ground gas to ingress into residential buildings (from BS8485)

Other papers relating to the design of gas mitigation measures (along with BS8485) are CIRIA C735 “Good practice on the testing and verification of protection systems for buildings against hazardous ground gases” and CIRIA C748 “Guidance on the use of plastic membranes as VOC vapour barriers.”

Coopers have appraised the potential risk of ground gases to provide an initial conceptual model in terms of source-pathway-receptor following current standards and guidance.

17.2 **Initial Conceptual Model - Potential Sources**

General: - In accordance with BS8485, Clause 4, “To complete an assessment of the risks posed by the presence of permanent and other ground gases, the potential sources of gas in and around a site should be identified; guidance on the collection of the relevant information is provided in BS 8576.”

In accordance with BS8576, Clause 6, the development of a preliminary conceptual site model is the first stage in determining the requirements for a program for gas monitoring. The initial stage of which is identification of “Potential sources of hazardous gases based on a review of the current and previous uses of the site and neighbouring land, and the underlying natural and man-made geology and hydrogeology;”

To aid classification of the risk of different sources of hazardous ground gas a decision matrix has been provided in BS8576, Clause 8.7, Figure 7, which classifies the generation potential of sources of hazardous ground gas from very low to very high.

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The review of potential sources and ground conditions identifies the site as at very low to negligible risk, detailed in the following appraisal.

Landfills (off site): - A detailed review of multiple sources of information has been undertaken to assess the gas generation potential for offsite landfills. The reviews have included the findings of a Groundsure Report (Appendix 2) where no landfills were referenced within 500m of the site based upon local authority, mapping, NRW historical data, NRW licensed landfill data, or planning data related to waste deposition.

A review of the NRW website identifies the closest historical landfill to be situated 530m to the north of the site, as shown in Appendix 1, and extract in Figure 10. Previous consultations and investigations have identified other sites close to the site to have not been impacted by landfill gas.

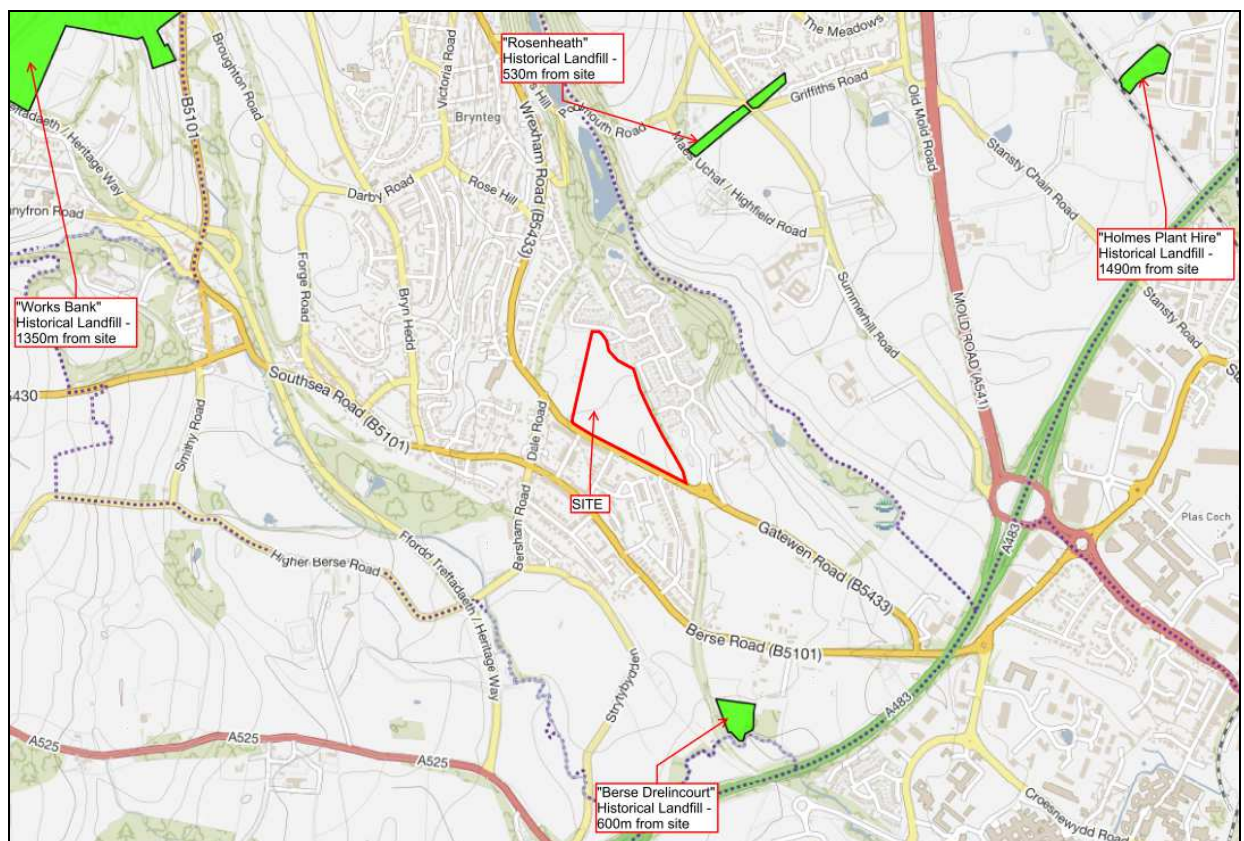


Figure 10: Annotated extract of NRW data of historical landfills in relation to development site (star)

The presence of glacial till interspersed with non-continuous layers of fluvio-glacial sands and gravels, overlying carboniferous fine sandstones and mudstones would not typically be considered as favourable for lateral migration of hazardous ground gases from distant sources. Given the distance of the landfills and ground conditions identified the site is considered to be unaffected by potential hazardous ground gases within the initial conceptual model.

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Coal Mining (on & off site) – Mine Workings: As detailed within Section 12, the site is situated within a Coal Authority coal mine reporting area, but outside of a high risk development area. Reports from The Coal Authority state that the site is not considered as within an area of known coal mine gas. Coal is commonly associated with trapped hazardous gases within pore spaces, primarily comprising of methane and carbon dioxide, although other gases including carbon monoxide can be present. Numerous historical coal mining disasters are attributed to the release of mine gas. Following abandonment of former coal mines these gases can migrate towards the surface where they can pose a significant risk to human health, including loss of life from asphyxiation and explosion.

BS8576 details that the risks posed by underground coal mine working varies by depth and age. The primary risks are where abandoned open workings fill with hazardous mine gas which can then be forced to the surface under pressure (particularly via water ingress or mine treatment works). The higher risks are posed for shallow and recent workings where it is less likely to have water returning to equilibrium and more likely to have pathways to reach the surface via cracks and fissures. Other preferential pathways for mine gas release to the surface require consideration such as migration via mine entries, geological faults and proposed construction (foundations, deep sewers, etc).

The Coal Authority mining report details that the site is underlain by workings of 6 No. seams at depths of 100m to 230m beneath the site, last working in 1935. The depth and age of workings would put the mine gas potential at a relatively low risk source. Coopers worked as consultants for the adjacent development of the former colliery where the mine shafts were grouted and capped, therefore negating these pathways for gas release. The geological maps however record the presence of geological fault terminating within the site. The fine grained strata of the carboniferous mudstones and sandstone, lack of shallow displacement of the fault and typical fault gouge would limit the preferential pathway of gases through faults towards the surface unless under considerable driving pressure (such as flooding).

The potential release of mine gases from deep and old mine workings would be defined as a low source potential under the initial conceptual model, although the sensitivity of the receptors would typically monitoring of shallow gases to determine if pathways for mine gas release are present.

Coal Mining (off site) – Colliery Spoil: The historical Ordnance Survey maps recorded the colliery spoil to be stockpiled to the east of the colliery, circa 160m from the site. Subsequent map editions also record the site to have continued to be used for processing of colliery spoil after closure of the mine and changes to the profile of the colliery spoil. Colliery spoil can include low grade coals, dusts and coal intermixed with mudstone and sandstone where coal mine gases (as described above) can be released.

The colliery spoil was recorded as a mound above ground and is still present to the east of the recent Bloor Homes development. Any gases associated with colliery spoil would therefore be anticipated to be released to the atmosphere as a preferential pathway, rather than migration beneath and horizontally through the ground. Investigations for the Bloor Homes development did not identify significant hazardous gases associated with the colliery spoil mound, although areas of relatively deeper made ground were determined as at risk from hazardous ground gases associated with degradable organic carbon.

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The colliery spoil is therefore considered as a negligible source under the initial conceptual model due to the absence of preferential pathways for lateral migration through the ground to reach receptors on site.

Former Ponds (on/off site): - As detailed in Section 7, the historical OS maps do not record any former ponds on or close to the source, therefore no potential for organic pond deposits (e.g. peat) or infill to generate hazardous ground gases on or near the site.

Deep Madeground (on site): - The investigations identified the majority of the site contained no madeground, with the exception of reworked soils within the area of the former reservoir. The materials present within the reservoir infill were gravels of ash, clinker, charcoal, glass, fragmented brick, metal and timber. The majority of the materials appeared to have derived from combustion (ash and clinker) which have a low degradable organic carbon, although timber would degrade over time. Gases generated from degradation of organic content are caused by bacterial action resulting in release of methane and/or carbon dioxide, subject to the availability of oxygen in the soils. The gases would migrate within the granular madeground towards the surface as preferential pathways rather than laterally through the lower permeability natural strata. The development layout includes the former reservoir within proposed open space areas and therefore no plots are proposed to be built over or adjacent to the reservoir, and therefore is not considered as a potential source of hazardous ground gases in relation to the proposed residential buildings.

Radon (on site): - As detailed in Section 13 – Radon, the site lies in an area where 10-30% of properties are affected by radon concentrations above the action level of 200Bq/m³. This is designated as a level where full radon protection measures are required for new buildings. As detailed in BR211 (2015), assessments and testing for radon ingress is only possible after occupation, therefore it is not possible to undertake on site monitoring of radon prior to construction. Full radon mitigation can supersede the risks of other gases, although commonly the membrane specifications will be higher for high concentrations of methane or where at risk from hazardous vapours.

Petroleum Hydrocarbons/Volatile Substance Vapours (on site): - The contamination section details there are no significant vapour risks associated with petroleum range hydrocarbons or other volatile organic substances, therefore

17.3 **Potential Pathways**

The interspersed glacial till and fluvioglacial sand and gravels will commonly limit significant lateral migration from distant sources. The development works will however include a variety of foundations, some of which are likely to partially penetrate the glacial deposits and provide preferential pathways for migration of gases towards the underside of the buildings (e.g. vibro stone columns).

Once gases generated have reached the surface they will dissipate rapidly through atmospheric diffusion unless confined by buildings or low points such as trenches. Hazardous gases beneath buildings can migrate through cracks or spaces in the floor slab and collect within the buildings. Any work in a confined space (including trenches) must assess the potential for hazardous gases to be present and health and safety provisions should be applied in accordance with HSE guidance.

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17.4 **Receptors**

Future Occupants: The primary receptors are anticipated to be the future occupants of the residential houses via the build up and ingress of potential hazardous gases/vapours through the ground floor slabs of the properties. These are considered highly sensitive receptors for the purposes of the conceptual model.

Adjacent residents: These can be exposed to hazardous gas if sources of gas are generated on site and migrate beyond the site boundary or preferential pathways exist for the horizontal migration of gases beyond the site boundary. The likelihood of this occurring is minimal due to the low potential for gas generation on site and pathways for gas migration being primarily vertical.

Construction/Maintenance Workers: Other receptors include construction workers, primarily through work within trenches or excavations where preferential pathways for the migration and collection of gases could occur. HSE guidance on safe work in confined space details potential dangers from gases within trenches, assessments required and precautions to take prior to entering a confined space. The appointment of a supervisor to ensure the necessary procedures and precautions are in place where construction workers intend to enter a confined space is advisable in accordance with HSE guidance.

17.5 **Conceptual Model Summary**

The conceptual model has demonstrated that generally, there is a low to no significant risk posed by ground gases to be present on site, with the primary risks associated with underlying mine workings which would require monitoring of shallow hazardous ground gases to determine if potentially migrating into the shallow strata where building foundations will provide pathways for gas migration. A summary of the sources, gas generation potential, pathways and risks to receptors is shown in Table 1.

Table 1: Summary of Initial Conceptual Model Associated with Hazardous Ground Gases

Sources	Gas	Receptor	Pathway	Risk
Landfills (off site)	N/A	N/A	N/A	No landfills within the surrounding area – Site Unaffected.
Coal Mining – Underground Workings (on/offsite)	Methane, carbon dioxide, & carbon monoxide,	Future occupants, construction/ maintenance workers/off site residents	Primarily within open workings where displacement can cause migration towards the surface. The presence of a geological fault may provide preferential pathways for migration towards the surface.	The mine workings are relatively deep (100m+) and old (last worked in 1935) which are defined as a relatively low risk potential for displacement of gases to reach the shallow soils where risks are posed to receptors – Low Source Potential.
Coal Mining – Colliery Spoil (offsite)	Methane, carbon dioxide, & carbon monoxide,	Future occupants, construction/ maintenance workers/off site residents	The colliery spoil is within a large above ground mound, approximately 160m from the site. Gases from these materials would be dispersed into the atmosphere as preferential pathway.	No preferential pathway for lateral migration of gases – Negligible Source Potential.
Former Ponds (on site)	N/A	N/A	N/A	No former ponds on or near to the site – Site Unaffected.
Deep Madeground (on site)	N/A	N/A	N/A	Generally none other than former reservoir infill, situated within area of proposed open space, therefore no significant risk of reaching proposed buildings – Site Unaffected.
Radon (on site)	Radon	Future Residents	Exposure to radon gases migrating into buildings through floor slab construction.	The site is within an area where Full radon precaution measures are required for new buildings to reduce the potential indoor concentrations of radon
Petroleum Hydrocarbons/ VOCs (on site)	N/A	N/A	N/A	No significant TPH and VOCs potential, therefore no vapour mitigation measures are required. – Site Unaffected.

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17.6 **Profile of Potential Hazardous Ground Gases**

The primary potential hazardous ground gases with the potential to be generated from the defined sources are methane and carbon dioxide from former mine workings, although as a minimum would require full radon precaution measures. The properties, pathways and hazards posed by these gases differ, with summary profile of the gases of concern contained in Tables 2 to 4 below.

Table 2: Profile of Methane as Significant Hazardous Ground Gas from BS8576

Methane - CH₄
Methane is a colourless, odourless, flammable gas. Methane is explosive at concentrations of between about 5% and 15% v/v (volume fraction) in air. Below 5% v/v (the lower explosive limit – LEL) there is insufficient methane to support combustion and above 15% v/v (the upper explosive limit – UEL) there is insufficient oxygen to support combustion. The flammability range of methane varies depending on the concentrations of other gases present. For example: • where carbon dioxide concentrations are >25% v/v, methane is non-flammable; and • if the oxygen concentration is reduced, the limits of flammability are reduced (e.g. at 13.45% v/v oxygen, the LEL and UEL are altered to 6.5% v/v and 7% v/v respectively, whilst at 13.25% oxygen, the mixture is incapable of propagating flame (see [14]). Methane is a low toxicity gas but can result in asphyxiation due to its ability to displace air and hence oxygen. Oxygen starvation occurs at 33% v/v methane, whilst at 75% v/v methane, death results after 10 minutes. Methane is less dense than air.

Table 3: Profile of Carbon Dioxide as Significant Hazardous Ground Gas from BS8576

Carbon Dioxide - CO₂
Carbon dioxide (CO₂) is a colourless, odourless gas. It is both highly toxic and an asphyxiant and can cause adverse health effects in concentrations greater than 0.5% v/v. It is denser than air. • 3% v/v carbon dioxide can result in headaches and shortness of breath, with increasing severity up to 5% v/v or 6% v/v; • 6% to 10-11% v/v causes visual distortion, headaches, increased heart rates, dizziness, mental depression, tremors and rapid loss of consciousness (less than 15 minutes) possibly resulting in death; • >22% v/v is likely to result in death. The Health and Safety Executive [74] has published the following limiting concentrations for work-related exposure: • Long-term exposure limit (LTEL – 8 hour period): 0.5% v/v; and • Short-term exposure limit (STEL – 15 minute period): 1.5% v/v. An additional hazard arises if air containing more than 0.5% carbon dioxide provides the combustion air to a central heating boiler or similar apparatus (e.g. it is drawn in from the sub-floor void). In these circumstances, there is a danger that carbon monoxide could be formed.

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Table 4: Profile of Radon Gas (primarily from BRE 211)

Radon – Rn
Radon (Rn) is a natural colourless, odourless, radioactive gas, formed from radioactive decay of small quantities of uranium and thorium in natural rock/soil. Radon poses chronic health risks primarily via increased rates of lung cancer. All indoor and outdoor areas contain low levels of radon. Higher risks are associated with areas where relatively high source material is present within rocks and soils. Radon release from the ground fluctuates during the day and year, associated with changes in temperature and pressure. Buildings can draw radon into the property, primarily through the temperature and pressure differential from the building in relation to the ground beneath, as such it is not viable to estimate radon risk for proposed buildings by monitoring radon in the ground or outdoor air. Protection measures are therefore defined by area based upon measured rates, with advice to monitor gases during normal use after occupation to determine if further reduction measures are required.

17.7 **Investigation Strategy Monitoring Wells and Response Zones**

As outlined above, the initial conceptual model defines the primary risk to be from radon, where Full Radon protection measures are required and cannot be monitored prior to occupation. The potential presence of hazardous mine gases however required monitoring due to the risk of gases migrating into the shallow drift strata where liable to be intercepted by the proposed foundation construction. The source potential for mine gases was considered as relatively low, due to the depth and age of workings, but due to the sensitivity of the proposed end use would warrant monitoring to determine if mitigation measures above that of Full Radon protection would be required.

CIRIA C665 (2007) made recommendations for prescriptive spacing of monitoring wells based upon source classification and receptor sensitivity. This failed to account for the common need to target monitoring at sources and primary pathways to disclose the risks. Changes to the prescriptive monitoring spacing were defined within BS8576 (2013), Chapter 8.4, which advocated appraisal of the conceptual model, gas migration, and determination if a non-targeted approach (grid based) was appropriate. Examples of circumstances where non-targeted methods would be appropriate were defined as:

- i) Permanent and consistent on site gas source;
- ii) VOCs in wide and undefined extent;
- iii) Where the conceptual model is unable to suitably define the gas targets, such that a phased monitoring approach would be appropriate.

Coopers detailed appraisal of the gas risk defined that mine workings at depths of 100m had a low potential of release of gases towards the surface. The pathways these can take are complicated by the geological conditions, where faults, cracks and fissures can enable migration of gases. A general spacing of monitoring wells around the site was therefore proposed to determine background levels of gases across the site. A total of 5 No. monitoring wells were installed, the positions of which are shown on Coopers Drawing No. 7791/01, and highlighted on an extract in Figure 11, below. The positions excluded the south eastern periphery of the site where proposed infiltration drainage ponds are intended (and liable to disturbance/influence from proposed infiltration testing) and the area of the former reservoir (intended public open space).

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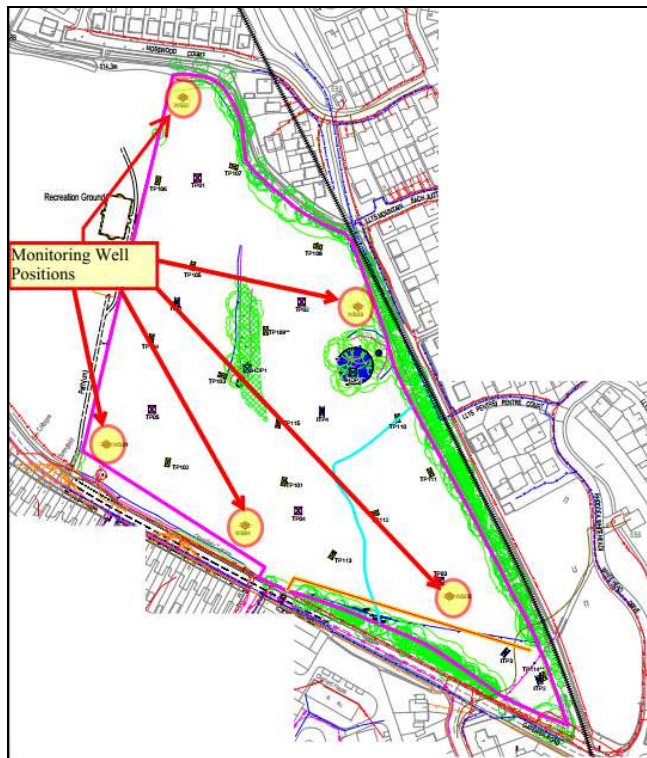


Figure 11: Showing gas monitoring positions.

Details of the monitoring wells and response zones are provided in the borehole logs, contained in Appendix 6. The gas monitoring wells constructed on behalf of Coopers consisted of 50mm HDPE pipe with slotted sections within a targeted response zone, geosoc surround to prevent silting up and inert gravel surround. Bentonite seals were constructed above the response zone to limit atmospheric gas ingress, with the base left open to identify any gas ingress from the basal and surrounding shallow strata. A dual valve system with downfeed was constructed to homogenise stratified gases, compliant with BS8576 (2013), was included, as shown in Figure 12, with flush stopcock cover.

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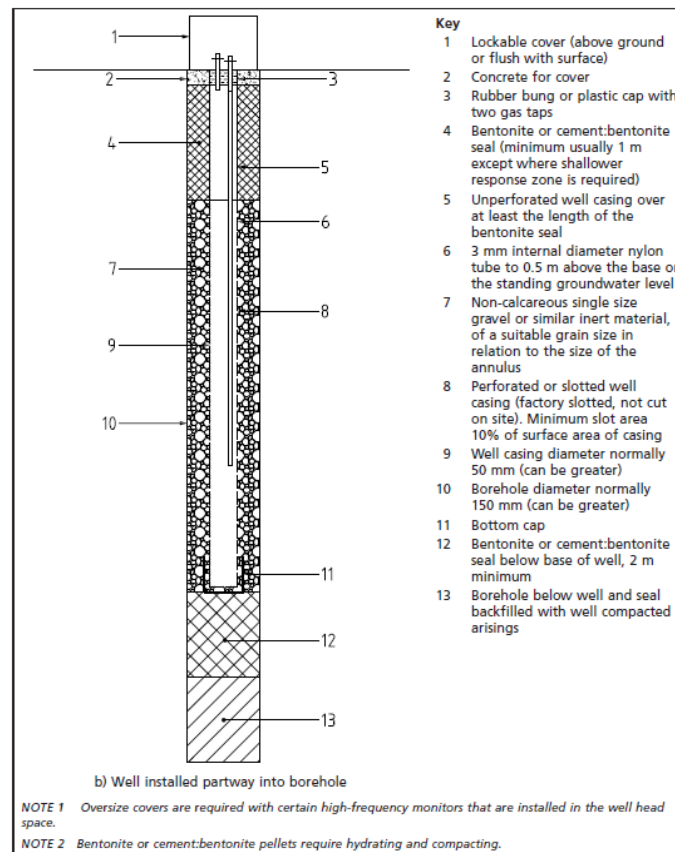


Figure 12: Extract of borehole monitoring well installation as recommended by BS8576

17.8 **Ground Gas Monitoring**

As detailed in BS8485(2015)+A1:2019 the gas monitoring procedures are to follow BS8576 (2013). This removes prescribed monitoring periods and frequencies with the onus transferred to the consultants to justify that their monitoring data is sufficient to characterise the site. Specific guidance on the requirements for gas monitoring duration is detailed within BS8576, Clause 8.6, in which the consultants should assess and appraise the risks based upon the levels of protection, as follows “*Gas monitoring does not necessarily need to be carried out under worst case conditions. It does not necessarily need to be at low or falling atmospheric pressure, but rather should be continued until it is unlikely that additional data will change the interpretation of the data, the outcome of the risk assessment, and the proposed remedial actions. This requires continued assessment of data as the monitoring progresses. One of the main considerations is to assess whether gas flow rates or concentrations could possibly increase and thereby affect the risk assessment and hence the choice of protective measures.*”

The approach to determining the sufficiency of the data is provided within BS8576, Annex F: Assessment of Whether Sufficient Gas Monitoring Data Have Been Collected. Table F.1 to F.3 within the BS8576 provide a decision matrix to appraise the sufficiency of the gas data.

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For the purposes of practically it is common practice to undertake a predefined set of monitoring visits to establish the ranges and variations that occur under different conditions and times. The monitoring proposed is to include 6 No. visits over a period of just under 3 months, which would be commonly considered appropriate for initial appraisal purposes. At the time of this report production a total of 3 No. visits has been complete with findings considered as interim, subject to completion of the monitoring. The monitoring is to include a range of atmospheric pressure and weather conditions, typically valid to allow an appraisal of variations occurring as a result of changes in conditions. At present no sufficient low pressure systems have been targeted for monitoring and will require targeting during further monitoring.

Coopers monitoring was undertaken with GA5000 gas analyser, manufacturer by QED (formerly Geotechnical Instruments) with a copy of the 6-month manufacturer calibration certificate provided in Appendix . The monitoring procedures by Coopers include an initial flow reading recorded at 10 second intervals over a period of 1 minute (to allow rates stabilise), followed by continuous monitoring of gas concentrations at 15 second intervals over a period of at least 5 minutes as recommended within BS8576. Following completion of the monitoring the bung is removed, water levels measures, followed by replacement of the bung and closing of valves.

The summary of peak and steady concentrations, flow rates and any relevant notes relating to the monitoring are contained on a summary table in Appendix 10. The range of results identified to date are summarised in Table 5 below

Table 5: – Summary of Ground Gas Monitoring

Borehole	Target Strata/Source	Response Zone (m bgl)	Pressure Range (mbar)	Peak Carbon Dioxide (% by Vol.)	Peak Methane (% by Vol.)	Min. Oxygen (% by Vol.)	Hydrogen Sulphide (ppm)	Carbon Monoxide (ppm)	Water Level (m bgl)	Steady Flow (l/h)
WS01	Drift (*1)	1.0-4.0	1008-1013	1.1-1.7	0.0-0.1	18.1-20.5	0	1	Dry	0.2-0.3
WS02	Drift (*1)	1.0-4.0	1008-1014	3.3-3.6	0.0-0.1	14.2-16.9	0	1-3	Dry	0.2
WS03	Drift (*1)	1.0-4.0	1008-1014	2.9-4.7	0.0-0.1	15.8-19.4	0	1-3	Dry	0.1-0.2
WS04	Drift (*1)	1.0-3.75	1008-1015	0.8-2.2	0.0-0.1	19.5-21.5	0	1-2	Dry	0.1
WS05	Drift (*1)	1.0-4.0	1008-1014	4.8-5.1	0.0-0.1	13.5-18.3	0	1-2	1.74-1.80	0.2

Notes:

*1 The gas source are mine workings at depths of 100m to 230m below ground level, the target for the monitoring is however the drift strata to determine if gases have migrated to shallow areas where potential to be intercepted by proposed building foundations.

17.9 Ground Gas Assessment

The assessments of gas risks includes analysis of concentrations of hazardous ground gases combined with ground gas flow rates to generate a Gas Screening Value (GSV) as outlined in BS8485. The GSV is calculated for methane and carbon dioxide following the below equation.

$$GSV = \frac{\text{concentration (by vol.)}}{100} \times \text{flowrate (l/hr)}$$

The site specific GSVs for methane and carbon dioxide are used to correlate gas risks based upon thresholds outlined within BS8485 and NHBC classification, summarised in Table 6. The standards reference that the GSV should be used as an aid to the ground gas risk assessment, and not replacing it. The decisions of requirements for mitigation requires determination by appropriately experienced persons with justification.

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Table 6: Thresholds for Gas Screening Values (GSV) in accordance with BS8485:2015+A1:2019 and NHBC Report No. 10627-R01

BS8485:2015+A1:2019			NHBC				
Classification	GSV (methane and carbon dioxide)	Limitations for Consideration	Classification	GSV (methane)	GSV (carbon dioxide)	Typical Maximum Carbon Dioxide	Typical Maximum Methane
CS1	<0.07	<1% CH ₄ , <5% CO ₂	Green	<0.13	<0.78	5	1
CS2	<0.70	<70 L/hr	Amber 1	<0.63	<1.60	10	5
CS3	<3.5	-	Amber 2	<1.60	<3.10	30	20
CS4	<15	-	Red	>1.60	>3.10	-	-
CS5	<70	-	-	-	-	-	-
CS6	>70	-	-	-	-	-	-

No GSVs are provided for other hazardous gases being monitored, such as carbon monoxide or hydrogen sulphide. As detailed within BS8576 the only existing thresholds available to assess these for occupational exposure limits (OEL). For carbon monoxide the short term OEL_{ST} is 200ppm and the long term OEL_{LT} is 30ppm. For hydrogen sulphide the OEL_{ST} is 10ppm and OEL_{LT} is 5ppm. It should be noted that the OEL_{LT} is based upon 8 hour exposure limit converted to an annual mean and the OEL_{ST} is based upon 15 minute exposures converted to an annual mean. The OEL's may therefore be inappropriate for residential end use. For carbon monoxide it may be suitable to assume the European Standard EN50291 (supersedes BS7860) for domestic carbon monoxide detectors in residential properties lower alarm limit of 30ppm is appropriate and is in correlation with the OEL_{LT}. It may be considered that where hydrogen sulphide is present in any consistent notable presence it could pose a risk to residential human health and will require assessment.

The current gas regime for each borehole is defined in Table 7 below. The screening values and peak concentrations are defined as Characteristic Situation 1 (CS1) and Green where no mitigation measures would be required. The maximum site wide values (using highest concentrations across the site with highest flow rate across the site) identifies the same risk classification.

Table 7 – Summary of GSV's for Each Borehole

Borehole Reference	Characteristic Carbon Dioxide (%)	Characteristic Methane (%)	Characteristic Flow Rate (l/hr)	GSV Carbon Dioxide	GSV Methane	BS8475 CS Class	NHBC Traffic Light Class
WS1	1.7	0.1	0.3	0.0050	0.0003	CS1	Green
WS2	3.6	0.1	0.2	0.0072	0.0002	CS1	Green
WS3	4.7	0.1	0.2	0.0094	0.0002	CS1	Green
WS4	2.2	0.1	0.1	0.0022	0.0001	CS1	Green
WS5	5.1	0.1	0.2	0.0102	0.0002	CS1	Green
Site Worst Case	5.1	0.1	0.3	0.0153	0.0003	CS1	Green

Notes to Table 7:

- Where applicable zero values have been changed to instrument LOD as GSV's include multiplication of values.
- Characteristic carbon dioxide and methane and flow rates are typically the maximum values during the monitoring, although consideration of steady state can be justified if monitoring data and assessment justify these are representative.

The Bellway Homes floor slabs are proposed to consist of precast suspended (block and beam) floor slabs where the NHBC traffic light designation would apply. The gas screening values would indicate the classification of Green, based upon the initial monitoring, where mitigation measures are not required.

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The peak carbon dioxide concentrations was marginally above 5.0% (maximum of 5.1%) where NHBC state they typically require Amber 1 mitigation. This is not a threshold and requires consideration of gas data and conceptual model. As highlighted in Card, et al (2019) a response zone within glacial till will commonly result in increased concentrations of carbon dioxide, this is caused by the introduction of oxygen from drilling of the borehole which reacts with small quantities of natural organic materials ($\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$). With negligible flow rates and migration is diffusion based with no driving force for gas ingress. There are no recorded cases in the UK of carbon dioxide generated from glacial till causing carbon dioxide emissions into buildings and therefore would not consider an increase from the CS1/green designation from this position.

The gas monitoring to date clearly has not disclosed any evidence of mine gas emissions into the shallow soils, supporting the initial conceptual model that the depth and age workings would be a low risk of causing mine gas release to the surface. The presence of low concentrations of carbon dioxide and methane therefore do not supersede the requirements for Full Radon protection.

17.10 **Radon Mitigation Design**

Full Radon

The design of Full Radon protection measures follow BRE 211 (2015) "*Radon: Guidance on protective measures for new buildings*". The radon protection measures are required for all occupied buildings. Radon protection is required for internal garages or where an adjoining garage includes an internal door to the house. No radon protection measures are required for detached garages.

The Full Radon designs include the provision of a virgin polymer, low density polyethylene (LDPE) membrane of a minimum thickness of 300µm (1200 gauge) within the floor slab construction with subfloor ventilation. BRE 211 details that this membrane may be liable to damage during installation and construction and that where there is risk of this a thicker and/or reinforced membrane should be installed. The membrane should be sealed (taped or welded), and provide a continuous barrier to the external wall of the building, other than service entry pipes which are to be sealed to the membrane. The position of the membrane within the floor slab construction is included within the enclosed typical details by floor slab construction.

As discussed previously, it is recommended that the future residents undertake radon monitoring within the first year of occupation. Should radon be identified above target levels then extraction of the subfloor ventilation layer will be required. Whilst these can be undertaken via the air bricks to the subfloor void, these can be difficult to install and some developers prefer the addition of a further access plug connecting the subfloor to the surface.

BRE 211 details that there is no specific statutory requirements for inspection of radon protection measures, however if not installed correctly then there is a high risk this will be identified following occupation and require costly remedial measures. BRE 211 therefore strongly recommends inspection of the membrane installation is carried out. Procedures for verification of gas membranes are included in Section 18 (subject to requirements of the local authority and NHBC).

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17.11 **Conclusions**

The refined conceptual model, based upon the ongoing monitoring, has indicated that there are no significant hazardous ground gases, with the exception of radon gas where Full Radon mitigation measures are required. Following completion of the monitoring the final results and assessment should be provided to confirm the gas risk and mitigation requirements.

The gas mitigation design system for Full Radon mitigation includes subfloor ventilation and provision of gas membranes within the floor slab construction. Typical construction details for gas mitigation measures within the floor slab construction are included in Appendix 15.

18.0 Remediation and Validation

18.1 **Remediation Proposals**

The remediation and validation proposals within this document are final proposals to be undertaken during the development, subject to approval by the Local Authority.

The contamination assessments have identified no contaminants, with cut and fill proposals outlining a surplus of material, meaning no further imported soils are likely. During these works it is likely that a redundant cement asbestos pipe will be encountered in the south eastern part of the site, which will require removal as outlined in Section 16. Following removal it is recommended that soils adjacent to the trench are tested to ensure no residual fibres or debris.

18.2 **Ground Gas Mitigation Measures**

As detailed within Section 17, all houses (and adjoining garages) require Full Radon protection measures including a certified radon membrane within the floor slab construction.

Refer to Section 17 for detailed explanation of the design system for gas mitigation.

Refer to Section 18.5 for details of verification of gas mitigation measures.

18.3 **Waste Exemptions/Requirements**

The reuse of soils within the earthworks process will include consideration of the excavated materials to be designated as a waste process, where registrations are recommended to follow the CL:AIRE Definition of Waste – Code of Practice (DoW-CoP) to ensure the soils are not designated as illegally deposited waste.

Where following the DoW-CoP the developer should establish a Material Management Plan (MMP) showing the location of the materials to be stockpiled and progressive use. The proposals should be agreed between the developer and their contractor. An independent suitably Qualified Person (QP) should review the information provided and complete the declarations for registration under the CL:AIRE system.

The QP will require regulatory approval of the proposals, including consultation with the Local Authority and National Resources Wales, prior to registering the declaration, which must be in place prior to the intended placement of the soils.

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18.4 **Validation of Gas Mitigation Measures**

As referenced previously BRE 211 details there is no regulatory requirements for validation of the installation of full radon protection, with the strong recommendation that this is complete. As post occupation monitoring is recommended it would be prudent for the developer to ensure that independent inspection of the radon protection measures are undertaken to minimise the risk of post occupancy testing identifying elevated levels of radon where remedial works would be required.

Some Local Authorities and/or NHBC Building Inspectors include checks on the installation, although commonly will not provide any written confirmation of this. It is therefore that to comply with the recommendations of BRE BR211 verification of the installation of the Full Radon precautions are complete for all plots.

The approaches for validation of gas membranes have advanced from prescriptive methods provided in early guidance by Coopers (e.g. CIEH – local authority guide to ground gas), to holistic methods within CIRIA C735. The holistic approach requires consideration of 4 key criteria in determining the verification strategy/plan for gas mitigation measures, detailed in Table 8.

Table 8 – Risk Based Approach to Determine Gas Inspection Program

Consideration	Assessment Criteria
Gas Regime	Risk based upon Characteristic Situation and levels of protection
Complexity of Designs	Based upon number of penetrations, building shape, steps in slab levels, etc.
Number of Plots/Buildings	The number of plots; where greater numbers are considered a high risk of variation and build duration.
Installation workforce	NVQ Level 2 qualification or general ground works contractor.

The gas regime is a higher designation of radon risk (Full Radon). The proposed buildings are standard residential houses, and an apartment block, with basic design (no anticipated steps in slab levels or unusual design requirements). The installer is unknown but assumed to consist of a general contractor without qualifications.

The precast suspended floor slab utilises a subfloor void as the primary form of protection, whilst not liable to damage it is relatively common for the passive venting to be incorrectly installed (commonly either through incorrect diameter pipework, insufficient spacing of venting on internal walls, or insufficient cranked vents on the external walls). As such the presence of the passive venting system should be witnessed prior to installation of the gas membrane.

The verification is proposed to include independent inspection of each gas membrane, by competent persons in the inspection of membranes. There are various schemes launched where to demonstrate competence, such as NVQ4, CL:AIRE qualification, or British Verification Council (BVC full membership). Should companies undertaking inspection not be able to demonstrate suitable competence then further testing of joints/whole membrane is recommended.

A summary of the verification regime is provided in Table 9.

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Table 9 – Gas Verification Requirements by Construction Method

Construction Method (Note *1)	Independent Inspection (Note *2)	Integrity Testing (Note *2)
Block and beam floor slab, proprietary gas membrane with very good passive venting.	All (Full Radon)	None.

Notes to Table 9:

*1 – Changes to any proposed slab type, construction personnel and achievement of NVQ level 2 training must be reported to consultants for reassessment of the gas regime and inspection strategy.

*2 – Inspectors of gas membranes installation to demonstrate competence/training in verification of gas membranes, for example NVQ4, CL:AIRE accreditation, or BVC membership, otherwise integrity testing is proposed to further support the verification. The method of testing would be subject to the methods of jointing and installation, which should be agreed with the NHBC and local authority.

The aspects to be verified are listed in Table 10 below, with example Photographs 6 to 17 showing example photographs.

Table 10: Gas Mitigation Measures Inspection Criteria (Table continued on following page)

Item	Inspection Notes
1. Product Verification	Confirmation that suitable products have been installed to consist of gas Membrane and tapes
2. General Condition	The membrane is to be inspected to ensure there are no tears, punctures or rips.
3. Membrane Subgrade	Commonly either insulation or sand blinding, check no gravel or other items with the potential to puncture.
4. Jointing/Welds	Checking the overlaps between membranes are correctly sealed, with correct tapes with sufficient overlaps or a good quality heat sealed weld if this method being utilised.
5. Creases/folds	Care must be taken to ensure that creases & folds within the membrane do not span over the jointing sections (bridging) as this provides an unacceptable gas pathway.
6. Service Entry Points	Verification of the presence of preformed tophats sealed to the pipe and membrane. If service entries are constructed using detailing strip or equivalent product then ensure adequate seal is achieved.
7. Corner Sections	Not cut and folded where punctures are present but concealed with tapes. Either formed with Detailing Strip or preformed corner units.
8. Reinforcement Spacers	Use of metal spacers/ties with potential to puncture the membrane would only be permitted with protection board.
9. Membrane Dirt/Debris	Whilst we appreciate the membranes are constructed on a real-world construction site, the membrane must be free of debris such as stones or mortar that would be liable to damage the membrane when weight is applied through subsequent construction. Whilst mud is inevitable on the membrane it must be kept to a minimal level to allow the membrane to be inspected and defects disclosed. If the membrane is not visible due to the amount of mud then it will be failed and need to be cleaned for reinspection.
10. Puncture Repairs	Punctures are relatively common and occasional damage with proper repair is not considered to be indicative of defective workmanship. All punctures require a patch that spans the damaged section by at least 150mm on each side.
11. Party Walls	The use of temporary blockwork for shuttering commonly involves placing the gas membrane above the blocks for the initial concrete pour. When this is removed, we advocate placing the membrane back to run flat through the party wall to allow this to be sealed and inspected on the subsequent plot. Alternative approaches are available but the membrane must not be cut and patched after the second plot is cast (due to additional damage, difficult repairs, and lack of inspection at this stage). Also if robust details adopted the membrane will need to drop through the cavity.
12. Door Thresholds	Care is required in relation to gas membrane positions through the wall cavity to the external wall around the door thresholds, closing the cavity, and protection beneath any sills. The use of preformed cloaking units and/or detailing strip protection would be recommended.
13. Wall Cavity Inspection	Confirming that proprietary gas membrane or gas DPC spans the external walls.

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Table 10: Gas Mitigation Measures Inspection Criteria ...Continued from previous page

	Item	Inspection Notes
	14. Internal Garage	<i>One of the most common problems/defects in construction occur for internal garages where the membrane positions need to account for variations in proposed slab level. Consideration of the following items requires attention</i>
a)	Sloping Floor	<i>Check if the developer has sloping garages, if so these are critical to membrane positioning and requires particular attention to membrane positions.</i>
b)	Internal Walls	<i>If sloping floor then check the membrane transitions at a low level through the internal wall to the plot to ensure it will not be exposed above the frontage of the sloping garage.</i>
c)	External Walls	<i>If sloping floor then check the membrane steps up within the external wall cavity of the internal garage to ensure it is not exposed above the fall of the garage.</i>
d)	Pillars	<i>Check the pillar/garage entrance section for the use of detailed strip to ensure not exposed around the entrance and closure of the cavity – refer to construction guide for details.</i>
	15. External Wall Venting	<i>Check positioning of vents are on 3 sides of dwelling at approximately 2m centres. Take photographs of vents on external walls for each plot.</i>
	16. Subfloor Venting Type Checked	<i>If stone venting (for suspended cast in situ concrete floors) then check the stone is single sized, 20-40mm.</i>
	17. Subfloor Venting Thickness	<i>The venting medium (void/stone) is of a designated thickness as shown on the gas design details. Photograph thickness of adjacent plots showing how large the void dimension will be with a staff.</i>
	18. Internal/Partition Wall Venting	<i>Check the spacing and dimensions of any interconnecting pipes between the subfloor venting medium.</i>



Photographs 6 and 7: Confirm presence of internal venting pipes, diameter and spacing. The typical spacing is 1 No. 75mm diameter pipe every 1m. This can change depending upon the pipe diameter, and the presence of spaces below the blocks and between the beams (dependant upon site specific construction variations) or changes by . This may not be able to be directly observed on each plot, depending upon the site specific design of gas protection measures. If not recorded then observation of other plots under construction, or requesting photographs to be taken by construction management can be deemed appropriate depending upon confidence in the construction as site progresses

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Photographs 8 and 9: Verify presence of cranked vents along the external walls and sufficient spacing. Areas of access points to internal garages or external adjoining garages may not be possible to have cranked venting and alternative construction options should be discussed where necessary. Note membrane shown is not specific for radon protection on this site and is only used as an example.



Photograph 10: Check general condition of membrane for punctures/tears etc – take panoramic photograph showing general condition. Note membrane shown is not specific for radon protection on this site and is only used as an example.

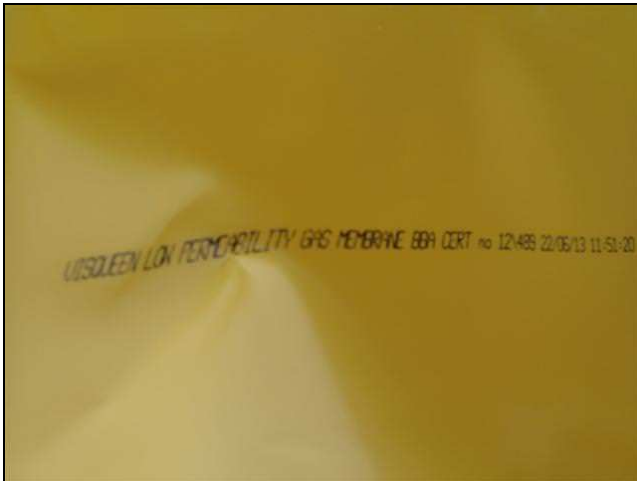
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Photographs 11 and 12: Check >150mm overlaps of membranes and proprietary tapes placed and sealed with photographs taken. Note membrane shown is not specific for radon protection on this site and is only used as an example.



Photographs 13 and 14: Check tophat is sealed to membrane and pipework with tapes, and Jubilee clip. Note membrane shown is not specific for radon protection on this site and is only used as an example.

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Photographs 15 and 16: If new delivery of product types is present and copies of supply tickets are not available then inspect product labels to confirm manufacturers and product types. Note membrane shown is not specific for radon protection on this site and is only used as an example.



Photograph 17: If no product labels are present then inspect stores for product types. Note membrane shown is not specific for radon protection on this site and is only used as an example.

18.5 **Conclusions**

No specific remediation requirements are needed with respect to contaminated land. Recommendations include testing of soils adjacent to a former cement asbestos pipe following safe removal, and verification of the installation of full radon protection measures.

19.0 **Management of Materials and Waste**

19.1 **Management of Materials**

Where materials are excavated for construction purposes these should be retained on site for engineering purposes where considered suitable for reuse in accordance with a sustainable development policy.

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Any intended reuse of soils is considered to potentially be designated as a waste activity requiring specific exemptions from the Environment Agency or Material Management Plan (MMP) following the CL:AIRE Development Industry Code of Practice for the Definition of Waste, Version 2 (or superseding versions if relevant). This guidance expects a Remediation Strategy to be produced for the site (assuming it to be contaminated) to determine which strata or areas of the site are considered to be contaminated with regard to the proposed land use (Route A). A Design Statement maybe utilised for those sites which have no contamination (Route B). **Subject to Statutory Body requirements this site is not expected to require a Remediation Statement, and reuse of natural strata are likely to be deemed as Route B.**

When applying for approval of the Code of Practice for this site, all engineering works on site have to be known. As part of the requirements, a full material management plan will be required. This will designate what material (including volumes) will be excavated, the likely positioning of stockpiles on site, as well as the fate of the soils. All aspects associated with site management and excavation works should be completed by the groundwork's contractor, or an engineer supervising the groundwork's contractor.

Tracking systems of materials, stockpiles and remediation processes will be required to be robust within the site management systems. Should the process of material tracking be considered non-robust, this may fail the test whether excavated materials may be considered non-waste. It should be noted that it must be proved the volume of soils to be transferred will be utilised on the receiving site, otherwise this material may be considered waste.

Direct transfer of naturally occurring soils may be undertaken, however a robust assessment of the materials has to be undertaken to confirm this material is suitable for use and uncontaminated. It should be noted that the degree of threshold for contamination will be judged on the receiving sites requirements (based on the proposed end use).

It is recommended that all materials where possible are segregated with stockpiled natural strata kept away from any goods or construction waste areas. Should material be disposed of at landfill, it may be possible to classify the natural material strata as a lower waste classification, however WAC (Waste Acceptance Criteria) analysis will commonly be required. This is an expensive form of analysis and should be completed on stockpiles prior to disposal or for transfer through the Code of Practice mechanism of movement of soils to hub sites (WAC analysis is not required for direct transfer).

The Code of Practice requires 4 No. factors to be addressed within the Material Management Plan:

- (1) Protection of human health and protection of the environment
- (2) Suitability of use, without further treatment
- (3) Certainty of use
- (4) Quantity of material

With regard to Box A within the Code of Practice (c.3.7, p.13), the material types encountered have been classified to determine the 'Categorisation of materials within the ground'. Should areas and volumes of strata be noted below, these are approximate values and require assessment by a qualified quantity surveyor. These volumes do not represent the volumes of soils likely to be excavated through any part of the demolition/construction phase of the site redevelopment, rather the anticipated total volume of that stratum. Additional investigation may be required to obtain more accurate detailed quantities:

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Table 11: Categorisation of materials within the ground in accordance with Code of Practice

- (1) Material that is capable of being used in another place on the same site without treatment*;
 - (2) Material that is capable of being used in another place on the same site following ex-situ treatment on site*;
 - (3) Material that is capable of being used in another development site without treatment (Direct Transfer);
 - (4) Material that is capable of being used in another development site following ex-situ treatment on another site e.g. Hub site*;
 - (5) Material that is not capable of being used on the site or elsewhere and requires recovery or disposal off site as waste; or
 - (6) Material that will be surplus to requirements and requires recovery or disposal off site as waste.
- * Having regard to the conceptual model (receptors and pathways) and appropriate risk assessment of the location where materials are to be used.

Topsoil (1), (3), or (6)

The natural topsoil from the site is inert and suitable for reuse or transfer.

Made ground – General (1), (3), or (6)

The only made ground encountered was within the areas of the former reservoir which are not proposed for significant changes to levels and intended to remain in place within the open space. Whilst not contaminated, the made ground contains glass, brick and timber which are not considered acceptable for reuse in gardens, if reused elsewhere on site these would be suitable, other than proposed garden areas.

Natural Strata – (1), (3) or (6)

Natural strata were identified to be uncontaminated. These may be utilised as subsoil or beneath roads and buildings (subject to suitable compaction for the end use).

19.2 Disposal of Waste Materials

Environment Agency Technical Guidance WM3 - Hazardous Waste, details the requirements for classifications of materials as hazardous waste. The soils will typically be classified as the below, with the exception of the pond infill:

17 05 04 soil and stones other than mentioned in 17 05 03 – not containing dangerous substances (WAC analysis may not be required).

Coopers anticipate that the all strata would be designated as non-hazardous waste, and may be acceptable as inert waste. It is advocated that any soils intended for disposal are segregated based upon likely disposal route, including segregation of topsoil, made ground and natural strata for specific testing agreed with the destination/disposal site.

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20.0 Sub Soil Classification

(Refer to Appendices 6 to 8, 11, 12 and 15)

20.1 General

Samples of the soils from the exploratory holes by Coopers were submitted to DETS (Appendix 11) and Murray Rix (Appendix 12).

In situ testing of soil strengths were also undertaken on the site during the ground investigation.

20.2 Results of In Situ Testing

In situ SPT testing was undertaken within small diameter boreholes, consisting of SPT N values at 1m intervals. Shear strengths of the clays were tested from recovered samples utilising a hand shear vane. Both forms of testing can be affected by the material properties/conditions, for example shear vanes will commonly produce false shears in gravelly clays and SPT N values influenced by water ingress. The logs reference certain areas where testing was considered likely to be spurious due to material properties.

Table 12 below details the in situ testing relevant to assessments of the construction requirements for this site. Further testing or assessments may be required for foundation design or earthworks purposes. It should be

Table 12: - Summary of In Situ Testing

Strata Type	Shear Vanes Readings (kPa)	SPT (N Value)
Glacial Clays	52-114	5-40
Fluvioglacial Sand/Gravel	N/A	8-11

20.3 Results of Laboratory Analysis

Table 13 details the geotechnical analysis relevant to assessments of the construction requirements for this site.

Table 13: - Summary of Geotechnical Analysis

Strata	SO ₄ (2:1) (water soluble) (mg/l)	SO ₄ (total sulphate) (%)	pH (-)	Mobile/Static (-)	PI %	Modified PI %	<425 Micron (%)
Glacial Clays	14	0.02	6.9	Static	18-21	13.9-19.7	77-94
Fluvioglacial Sand/Gravel	47-1400	0.09-0.26	6.8-7.4	Mobile	N/A	N/A	-

20.4 Interpretation

Frost Susceptibility **Fluvioglacial Sand – Frost Susceptible (assumed).**

Shrinkage Potential **Low (based upon NHBC modified PI)**

Soil Classification: Based upon BRE Special Digest 1 (2005), the Design Sulphate (DS) class, Aggressive Chemical Environment for Concrete (AC) class, and Design Concrete (DC) class for each of the strata types is given below:

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Glacial Clay – DS-1, AC-1s, DC-1s
Fluvioglacial Sand/Gravel - DS-2, AC-2, DC-2

Any fill material to be imported onto the site should be tested and should not exceed the classifications given above. The designated concrete mix by end use is detailed in Table 14 (below).

Table 14: Sub-structure ready mix concrete designations by end use over the entire site

Use as substructure and ground floors		Ready-mixed concrete (designated mix)
General Use:		
• Rough blinding (non-structural)	-	FND2
• Infill	-	FND2
• Unreinforced oversite concrete below timber floors	-	FND2
• Structural blinding and overbreak	-	FND2
• In situ external concrete for drives and paths	-	PAV1
• In situ external concrete foundations for precast concrete paving slabs	-	FND2
• Fill to wall cavity	-	FND2
• Solid filling under steps	-	FND2
Floor Slabs:		
• House or garage with reinforced concrete floor slab, either suspended or precast.	-	RC35
• House with non-reinforced slab (ground bearing) with either:		
a) Permanent finish to be added, e.g. screed or floating floor.	-	GEN1
b) No permanent finish to be added, e.g. carpet.	-	GEN2
• Garage with non-reinforced slab (ground bearing)	-	GEN3
Foundations:		
• Strip foundations	-	FND2
• Trench fill	-	FND2
• Other mass concrete foundations	-	FND2
• Reinforced concrete footing	-	C28/35

Notes to Table 14:

Worst case sulphate conditions over the entire site are ACEC Class AC-2, and Design Chemical Class DC-2.

Classification and designation in accordance with NHBC guidance, Section 3.1 – Table 6, and BS8500-1, 2006.

The above conditions represent the worst case conditions identified within the testing of soils on the site.

Any fill material to be imported onto the site should be tested and should not exceed the classifications given above.

21.0 Trees

(Refer to Appendix 15)

As detailed within Coopers site walkover, trees/hedgerows are present on the periphery of the site, generally consisting of mature broadleaf species.

Consultation is advised with Wrexham Council regarding any Tree Preservation Orders and any proposed felling should be agreed with the council in advance.

The shallow cohesive strata are subject to influence by changing moisture content associated with tree roots. Where existing trees are removed or their roots severed by construction of foundations, rehydration of clay subsoils may occur causing the clay to swell or 'heave'.

As immature to semi-mature trees grow the root ball expands and can cause the clay beneath foundations to shrink causing subsidence. Where heave or subsidence is likely to occur, it is possible that it will affect the foundation/slab designs for any proposed dwelling in their vicinity.

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The glacial clay strata have been tested and determined as consistently low shrinkage potential in accordance with NHBC guidance. Assessments of the tree influence in relation to current/proposed ground levels is therefore required for foundation designs. Assessments of the likely zones of potential heave have been provided on Coopers Foundation Zone Plan within Appendix 15, although detailed assessments will be required once the development layout is finalised.

Care must be taken to ensure that any existing trees scheduled for retention are not adversely affected by construction operations. Further guidance on this aspect of site works is given in the British Standards “*Guidance for Trees in Relation to Constructions*”, BS5837.

22.0 Ground Floor Slabs

22.1 General Requirements

Based upon our client’s preferred floor slab construction, all plots will include precast suspended (block and beam) slabs. Subject to commercial preferences precast suspended (block and beam) floor slabs can be adopted, although would require inclusion of stone ventilation layers for gas mitigation (radon).

22.2 Gas Precaution Measures

Refer to Section 17 - All plots will require a minimum of Full Radon protection measures.

23.0 Foundations

(Refer to Appendices 6 to 8 and 15)

The key factors in determining the foundations on this site are the proposals for regrading of site levels and tree influence in areas of cohesive strata. An indicative foundation schedule has been provided taking into account the proposed cut and fill levels and likely zones of tree influence.

23.1 Development Proposals

The site is proposed for residential development by Bellway Homes (North West), comprising of 112 No. residential plots, of which 88 No. are traditional residential properties with the remaining plots within 2 No. apartment blocks. The housing includes a combination of traditional detached, semi-detached and 3-6 block mews residential houses with associated roads, private driveways, garages, gardens and landscaping. . The proposed development layout is shown on APD Drawing “Planning Layout”, referenced BHNW130. PL01, revision A, dated 24 September 2021. An extract of which is overlain on Coopers Drawing No. 7791/Fdz, within Appendix 15. It is also assumed that all materials and workmanship will comply with the Building Regulations and the NHBC Standards.

23.2 Ground Conditions

The general ground conditions comprise shallow natural strata consisting of firm, firm to stiff, or stiff glacial clay or loose to medium dense, or medium dense sands/gravels. In situ testing identified the strengths to be variable, but suitable to assign an allowable bearing capacity of 100kN/m² for both strata types with settlement of <25mm.

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23.3 **Tree Influence and Heave Potential**

The glacial clays have been tested and confirmed as low shrinkage potential based upon the NHBC modified PI approach. This was the same designation as identified on the adjacent developments.

Low shrinkage potential clays require foundation depths to be assessed accounting for trees in general accordance with NHBC Standards, Chapter 4.2. Heave mitigation is not required for concrete foundations, but is required beneath ground beams and floor slabs, to mitigate vertical heave of 50mm.

23.4 **Allowable Bearing Pressure**

The allowable bearing pressure of the both clays and sands are assigned 100kN/m², limited by settlement (rather than bearing capacity failure).

23.5 **Foundation Recommendations**

The outline foundation types proposed are shown on Coopers Drawing No Coopers Drawing No. 7791/Fdz, within Appendix 15, comprising of the following types.

Nominally Reinforced Strip Foundations

- **For properties founded on firm, firm to stiff, stiff, or very stiff clay and/or loose to medium dense or medium dense sand at less than 1.25m depth from proposed slab level.**
- Maximum safe bearing strata limited to 100kN/m².
- Minimum foundation depth of 0.9m below finished ground level (to account for services over strip foundations).
- Where formation depth varies the foundations should be stepped in accordance with NHBC Standards.
- Refer to typical foundation detail, drawing No. 7791/Rn in Appendix 15.

Mass Concrete Trench Fill Foundations

- **For properties founded on firm, firm to stiff, stiff, or very stiff clay and/or loose to medium dense or medium dense sand at greater than 1.25m depth but less than 2.5m from proposed slab level.**
- The viability for deeper mass concrete trench fill is largely determined by trench stability, where upfill is generally >1.5m coopers have proposed pile/vibro foundations due to likely reduced trench stability in reworked materials.
- Maximum safe bearing strata limited to 100kN/m².
- Where formation depth varies the foundations should be stepped in accordance with NHBC Standards.
- Refer to typical foundation detail, drawing No. 7791/Tf in Appendix 15.

Mass Concrete Trench Fill Foundations with Heave Precautions

- **For properties founded on firm, firm to stiff, stiff, or very stiff clay and/or loose to medium dense or medium dense sand at greater than 1.25m depth but less than 2.5m from proposed slab level, and within the likely zone of heave influence from trees.**
- Due to low shrinkage potential clays no compressible material (e.g. clay board) is required for the foundations, although heave mitigation is required for the floor slabs.

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- The viability for deeper mass concrete trench fill is largely determined by trench stability, where upfill is generally >1.5m coopers have proposed pile/vibro foundations due to likely reduced trench stability in reworked materials.
- Maximum safe bearing strata limited to 100kN/m².
- Where formation depth varies the foundations should be stepped in accordance with NHBC Standards.
- Refer to typical foundation detail, drawing No. 7791/TfH in Appendix 15.

Doubly Reinforced Strip Foundations on Vibro Stone Columns

- **For properties where depth to foundation formation strata is typically >2.5m below slab level, or >1.5m or upfill and outside of areas of potential tree influence.**
- Any placement of materials as part of regrading of site levels should be of approved materials and placed in accordance with contractor's specifications.
- The suitability for vibro treatment must be determined by the specialist contractor due to variations in rig specifications.
- The developer must be careful to ensure proposed planting and hedgerows are designed to not impact shallow footings.
- The upper 0.6m of the vibro stone column are typically sacrificial.
- Bearing capacity limited to 125kN/m².
- Madeground should be approved as suitable for treatment in accordance with NHBC Standards Chapter 4.5 and should be determined by the specialist contractor undertaking the vibro stone columns, who will provide specifications and limitations to the proposed treatment.
- Confirmation of the suitability of the site for treatment should be provided to the NHBC for approval, with information supplied in accordance with NHBC Standards Chapter 4.5(4).
- Confirmation should be sought with the local authority regarding any vibration issues associated with vibro stone column foundations.
- The platform for the rig installing the vibro stone columns will need to be assessed and if required designed in accordance with BR470.
- The stone column layout should be designed by the specialist contractor and submitted to the NHBC for approval.
- The installed stone columns will require verification testing in accordance with NHBC Standards, Chapter 4.5 (12) which are likely to comprise of 600mm diameter plate tests and dummy footing test/mini zone tests. The testing methods and frequency should be agreed with the NHBC in advance of commencing construction.
- Coopers typical design of doubly reinforced strip footings assumes the stone columns diameter are between 450mm to 600mm, maximum centre misalignment of 150mm, with a maximum spacing between columns of 1800mm to span between stone columns. The NHBC also specifies the columns should be spaced at a maximum of 2000mm, and misaligned by less than 150mm.
- In the event of unforeseen circumstances which influence the efficiency of the treatment and require remedial measures these should be immediately reported to the NHBC.
- The installation contractor will be required to record and provide details of all works, including information concerning the treatment, depths, volume of stone used, on-site changes, and any other relevant information relating to the works.
- Upon completion of the vibro treatment the designers should provide confirmation of the suitability of the installation, including review of the test results.
- Refer to typical foundation detail, drawing No. 7791/VD in Appendix 15.

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Piled Foundations with Associated Ground Beams

- For properties where depth to foundation formation strata is typically >2.5m below slab level, or >1.5m or upfill and within areas of potential tree influence but outside of heave potential zones.
- Confirmation of the suitability for the proposed piled foundations should be sought from the piling contractor prior to construction.
- The determination of the number of piles (and therefore the loads) against pile length is largely commercial and typically determined by the contractors. Assuming piles to be friction bearing within glacial till, likely to be up to 10m in length.
- Cable percussive boreholes may be required for pile design purposes and associated approvals.
- Piling platform to be designed in accordance with BR470 and subject to the rig specifications.
- Confirmation should be sought from the local authority regarding noise or vibration issues associated with driven piles.

PH - Piled Foundations with Associated Ground Beams Including Heave Precautions/Designs

- For properties where >2.5m depth of tree influence within cohesive strata including heave precautions.
- Pile lengths to be designed for negative skin friction, increasing pile depths.
- Heave precautions are required beneath all ground beams (low shrinkage potential clays) to accommodate 50mm compression but not on the inside face of external wall ground beams to accommodate.
- Confirmation of the suitability for the proposed piled foundations should be sought from the piling contractor prior to construction.
- The determination of the number of piles (and therefore the loads) against pile length is largely commercial and typically determined by the contractors. Assuming piles to be friction bearing within glacial clays, likely to be up to 10m-15m with piles to be designed to account for negative skin friction resulting from heave.
- Cable percussive boreholes may be required for pile design purposes and associated approvals.
- Piling platform to be designed in accordance with BR470 and subject to the rig specifications.
- Confirmation should be sought from the local authority regarding noise or vibration issues associated with driven piles.
- Refer to typical foundation detail, drawing No. 7791/PH in Appendix 15.

24.0 Trench Side Stability

(Refer to Appendix 7 and 8)

The excavations undertaken during the ground investigation demonstrated short term stability within glacial clays, although areas of collapse with depth occurred in the fluvioglacial sand/sand and gravel. Should trenches need to remain open or require manned entry then they should be supported at all times or, where suitable, safely battered. Battering of excavations should be avoided in the proximity of existing structures without assessment from experienced engineering personnel.

Trench excavations for foundations/services must be adequately supported at all times and should be in accordance with the recommendations of CIRIA Report 97: Trenching Practice.

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Further guidance on this aspect of site works is given in the British Standards for “Workmanship on Building Sites”, BS8000, Parts 1 and 14, and in the Construction Industry Training Board’s Site Safety Note 10.

Excavations within drift deposits revealed by this investigation should be within the capacity of conventional hydraulic plant without the use of mechanical breakers.

25.0 Dewatering and Infiltration Rates

(Refer to Appendices 8, 9 and 15)

The ground investigation included testing of infiltration rates for soakaway design compliant with BRE 365. Coopers excavated 4 No. infiltration test pits, referenced ITP01 to ITP04, the location of which was agreed in advance with the developer and locations recorded on Coopers Site Plan, Drawing No. 7791/01 in Appendix 15.

The test pits were limited in depth by trench stability, with ground conditions identified as variable clays, sands and gravels (refer to Coopers Infiltration Test Pit Logs within Appendix 8). Upon excavation of each position a 50mm slotted pipe was installed and backfilled with 20mm-40mm single sized stone (no fines). Water levels were then recorded prior to filling with clean water to close to the underside of the topsoil/top of gravel; delivered from a large capacity bowser (tractor driven).

The tests were proposed to be completed 3 times to simulate saturation following periods of heavy rain, although this was not possible on all positions due to the infiltration test pits either not draining during testing, or draining faster than possible to fill from a 2000 gallon bowser.

The results of the testing are provided in Appendix 9, demonstrating the infiltration rates were reflective of the geological conditions and comparable with findings from previous investigations on and near to the site. Drainage rates were very high where the test pits intercepted the sands and gravels, and relatively slow where confined within only clays or very clayey sands.

Typical Infiltration Rates:

- Sand and Gravel = 1.82×10^{-4} to 4.9×10^{-4} m/sec.
- Clayey Sand = 3.34×10^{-6} to 4.9×10^{-6} m/sec.
- Very Sandy Clay = N/A (infiltration rates too slow to determine).

The results of the infiltration testing confirm the ground conditions are generally suitable for construction of traditional soakaways where they intercept sands and gravels but would fail to drain sufficiently in clays. Specific assessments and further investigation may be required to determine the depth of sands and gravels in areas of dedicated drainage, subject to final designs.

Any pumping of groundwater should not be discharged into the existing sewer systems or brooks/ditches without prior agreement from the Environment Agency and Local Authority. Further guidance can be obtained from the CIRIA Report 113 entitled “Control of Groundwater for Temporary Works”.

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It should be noted that seasonal factors may affect changes in groundwater levels at the site. Consequently, dewatering may be more prevalent in the winter or at times of prolonged rainfall for shallow foundations or drainage trenches.

26.0 Road Sub-Grade

(Refer to Appendix 6 to 8 and 15)

- 26.1 Following site clearance, vegetation removal and earthworks regrading levels the anticipated roads and car parking sub-grade materials are likely to comprise a combination of natural and reworked clays, sands and gravels.
- 26.2 Road formation within natural strata are estimated to have CBRs of up to 5% in natural clays and up to 20% in natural sand, subject to proof rolling and surface conditions, based upon text book values, although reworked strata will be placed as part of an earthworks process, compacted in layers to a highways specification with testing to confirm suitable placement.
- 26.3 Proposals are subject to the review of Local Authority – Highways Department. However, we would recommend that all sub-grade materials are in situ CBR tested at proposed road formation level prior to final pavement design.
- 26.4 It is recommended that if initial roads and sewer construction is proposed to commence during the winter months then a longer period should be allowed for construction due to the potential for weather disruptions to the site.

27.0 Conclusions and Further Actions

27.1 Conclusions

The site investigation has identified the ground conditions to generally consist of topsoil onto a combination of fluvioglacial sands and gravels, and glacial clays.

Chemical testing from the investigation identified no contaminants within the site.

Full Radon precaution measures are available for all plots, including adjoining or internal garages.

27.2 Further Actions

Further action which Coopers consider will be required to progress the development status could include, but not necessarily be limited to: -

- Submit site investigation report for local authority and NHBC for approval.
- Report on findings from ongoing gas monitoring.
- Consultation with Local Authority and National Resources Wales regarding proposals for use of CL:AIRE Definition of Waste – Code of Practice (DoW-CoP).
- Produce Material Management Plan (MMP) for the reuse of soils on site.
- Registration of MMP following DoW-CoP.
- Undertake testing of soils following removal of asbestos cement pipeline.
- Installation and verification of full radon mitigation measures in accordance with BRE211 and CIRIA C735.

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28.0 References

- Published geological maps, memoirs and the British Geological Survey website.
- Groundsure Historical Maps.
- Groundsure Enviro+Geo Insight Report.
- Historical aerial photography supplied by Royal Commission on the Ancient and Historical Monuments of Wales.
- The Coal Authority - Con29M Coal mining report.
- BGS Technical Report WA/91/4 (1991) and associated maps – Applied Geological Mapping in the Wrexham Area: Geology and Land Use Planning.
- Card, G., Lucas, J. and Wilson, S. (2019) Risk and reliability in gas protection design – 20 years on: Part 1, in Ground Engineering, August/September 2019.
- Donnelly, L.J., (2006) A Review of Coal Mining Induced Fault Reactivation in Great Britain, in Quarterly Journal of Engineering Geology and Hydrogeology, Vol.39.
- A review of data held in the Coopers archives.
- A review of desk study data obtained from internet sources.
- Findings of trial pits and boreholes undertaken by or on behalf of Coopers.
- Findings of laboratory testing by DETS Ltd.
- Findings of laboratory testing by Murray Rix.
- DOE/ARUP Map of Mining Instability in the Northwest.
- The Coal Authority Technical Guidance Note 1 (TGN1/2019).
- BS 3882:2015 - Specification for topsoil and requirement for use.
- BS 5837:2012 - Trees in relation to design, demolition and construction. Recommendations.
- BS 5930:2015 - Code of Practice for Ground Investigations.
- BS 8000-11:2011 - Workmanship on building sites. Internal and external wall and floor tiling. Ceramic and agglomerated stone tiles, natural stone and terrazzo tiles and slabs, and mosaics. Code of practice.
- BS10175: 2011+A2:2017 - Investigation of potentially contaminated sites. Code of practice.
- BS EN 1997-1:2004 - Eurocode 7. Geotechnical design. General rules.
- BS 8485:2015+A1:2019 – Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments.
- BS 8576:2013 – Guidance on Investigations for Ground Gas (Permanent Gases and Volatile Organic Compounds (VOCs)).
- BRE Special Publication 1– Concrete in Aggressive Ground, 2005.
- BRE/EA Report 414: Protective Measures for Housing on Gas Contaminated Land, 2001.
- BRE: Cover Systems for Land Regeneration, 2004.
- BRE Report 211, Radon: Guidance on Protective Measures for New Dwellings, 2015.
- CIEH and LQM Report Generic Assessment Criteria for Human Health Risk Assessment, 2nd Edition, July 2009.
- CIEH and LQM Report: The LQM/CIEH S4ULs for Human Health Risk Assessment, 2015.
- CIRIA Report 97 – Trenching Practice, 1992.
- CIRIA Report 113 - Control of Groundwater for Temporary Works, 2000.
- CIRIA Report C665: Assessing risks posed by hazardous ground gases to buildings, 2006.
- CIRIA Report C733: Asbestos in soil and made ground, 2014.
- CIRIA Report C735: Good Practice on the testing and verification of protection systems for buildings against hazardous ground gases, 2014.
- CIRIA Report C765 – Asbestos in soil and made ground good practice site guide, 2017

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- CIRIA Report SP168: Asbestos in soil and made ground: a guide to understanding and managing risks, 2014.
- CITB – Report GE700: Construction Site Safety.
- DEFRA SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination, 2014.
- DEFRA Environmental Protection Action 1990: Part 2A – Contaminated Land Statutory Guidance, revised 2012.
- Department for the Environment, Transport and the Regions: Passive Venting of Soil Gases beneath Buildings, Research Report, Guide for Design, Volume 1, September 1997.
- Design Manual for Roads and Bridges Volume 7, Section 2, Standard Interim Advice Note 73/06 Revision 1.
- Environment Agency – Land Contamination Risk Management, (<https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm>), 2020.
- Environment Agency - Technical Advice to Third Parties of Controlled Waters for Part IIA of the EPA 1990, 2002.
- Environment Agency Report: SC050021/Final Technical Report 1 - A review of body weight and height data used within the Contaminated Land Exposure Assessment model (CLEA), 2009.
- Environment Agency Report: SC050021/SR2 - Human health toxicological assessment of contaminants in soil, 2009
- Environment Agency Report: SC050021/SR3 - Updated technical background to the CLEA model, 2009.
- Environment Agency Report: SC050021/SR4 - CLEA Software (Version 1.04 beta) Handbook, 2009.
- Environment Agency Report: SC050021/SR7 - Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guidance values, 2009.
- Environment Agency, Good practice for decommissioning redundant boreholes and wells, 2012.
- Environment Agency, Technical Guidance WM3: Waste Classification. Guidance on the classification and assessment of waste(1st edition 2015).
- Health and Safety Executive: Managing and Working with Asbestos - Control of Asbestos Regulations 2012. Approved Code of Practice and guidance, 2013.
- The Law Society's Guidance Notes and Directory for Coal Mining Searches.
- NHBC Standards.
- NHBC Report No. 10627-R01 (04): Guidance on Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are Present, January 2007.
- Waste Management Report No. 27: Landfill Gas, Department of the Environment, 1991.
- Waste Management Paper No. 26A: Landfill Completion, Department of the Environment, 1994.