Appendix K
Attenuation Calculations

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	98.525	0.525	45.1	568.6	O K
30 min Summer	98.627	0.627	45.1	680.2	O K
60 min Summer	98.736	0.736	45.1	797.8	O K
120 min Summer	98.831	0.831	45.1	900.9	O K
180 min Summer	98.863	0.863	45.1	935.1	O K
240 min Summer	98.878	0.878	45.1	952.0	O K
360 min Summer	98.888	0.888	45.1	962.5	O K
480 min Summer	98.881	0.881	45.1	955.4	O K
600 min Summer	98.866	0.866	45.1	938.4	O K
720 min Summer	98.845	0.845	45.1	915.8	O K
960 min Summer	98.790	0.790	45.1	856.5	O K
1440 min Summer	98.662	0.662	45.1	717.6	O K
2160 min Summer	98.502	0.502	45.1	544.2	O K
2880 min Summer	98.390	0.390	45.0	422.3	O K
4320 min Summer	98.270	0.270	42.7	292.4	O K
5760 min Summer	98.232	0.232	35.9	252.0	O K
7200 min Summer	98.209	0.209	31.0	226.8	O K
8640 min Summer	98.192	0.192	27.3	208.4	O K
10080 min Summer	98.179	0.179	24.5	194.4	O K
15 min Winter	98.590	0.590	45.1	639.5	O K
30 min Winter	98.708	0.708	45.1	767.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	164.198	0.0	582.3	18
30 min Summer	100.796	0.0	717.7	33
60 min Summer	61.875	0.0	892.8	62
120 min Summer	37.983	0.0	1097.5	120
180 min Summer	28.551	0.0	1238.2	166
240 min Summer	23.316	0.0	1348.8	196
360 min Summer	17.526	0.0	1521.4	260
480 min Summer	14.313	0.0	1657.1	330
600 min Summer	12.232	0.0	1770.5	400
720 min Summer	10.759	0.0	1868.9	470
960 min Summer	8.754	0.0	2027.5	608
1440 min Summer	6.545	0.0	2273.0	866
2160 min Summer	4.894	0.0	2558.3	1228
2880 min Summer	3.982	0.0	2774.5	1560
4320 min Summer	2.943	0.0	3070.9	2208
5760 min Summer	2.374	0.0	3313.1	2944
7200 min Summer	2.010	0.0	3505.4	3672
8640 min Summer	1.755	0.0	3669.9	4408
10080 min Summer	1.564	0.0	3811.9	5136
15 min Winter	164.198	0.0	653.7	18
30 min Winter	100.796	0.0	805.3	32

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	98.833	0.833	45.1	903.2	O K
120 min Winter	98.943	0.943	45.1	1022.7	O K
180 min Winter	98.984	0.984	45.1	1066.9	O K
240 min Winter	98.996	0.996	45.1	1079.4	O K
360 min Winter	99.000	1.000	45.2	1083.5	O K
480 min Winter	98.983	0.983	45.1	1065.3	O K
600 min Winter	98.954	0.954	45.1	1033.9	O K
720 min Winter	98.918	0.918	45.1	995.2	O K
960 min Winter	98.830	0.830	45.1	899.8	O K
1440 min Winter	98.621	0.621	45.1	673.3	O K
2160 min Winter	98.392	0.392	45.0	425.2	O K
2880 min Winter	98.276	0.276	43.4	299.5	O K
4320 min Winter	98.219	0.219	33.1	237.2	O K
5760 min Winter	98.190	0.190	26.9	206.5	O K
7200 min Winter	98.172	0.172	22.8	186.4	O K
8640 min Winter	98.159	0.159	20.0	171.9	O K
10080 min Winter	98.148	0.148	17.8	160.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	61.875	0.0	1000.7	62
120 min Winter	37.983	0.0	1230.0	118
180 min Winter	28.551	0.0	1387.6	172
240 min Winter	23.316	0.0	1511.4	222
360 min Winter	17.526	0.0	1704.9	278
480 min Winter	14.313	0.0	1856.8	356
600 min Winter	12.232	0.0	1983.8	434
720 min Winter	10.759	0.0	2094.0	508
960 min Winter	8.754	0.0	2271.7	656
1440 min Winter	6.545	0.0	2547.3	922
2160 min Winter	4.894	0.0	2865.9	1256
2880 min Winter	3.982	0.0	3108.3	1532
4320 min Winter	2.943	0.0	3441.2	2244
5760 min Winter	2.374	0.0	3711.0	2944
7200 min Winter	2.010	0.0	3926.7	3680
8640 min Winter	1.755	0.0	4111.3	4408
10080 min Winter	1.564	0.0	4271.4	5144

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	406450 374300 SK 06450 74300
C (1km)	-0.025
D1 (1km)	0.411
D2 (1km)	0.398
D3 (1km)	0.369
E (1km)	0.301
F (1km)	2.404
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.940

Time From:	(mins) To:	Area (ha)
0	4	1.940

Model Details

Storage is Online Cover Level (m) 100.000

Tank or Pond Structure

Invert Level (m) 98.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	1084.0	1.000	1084.0	1.001	0.0

Hydro-Brake® Optimum Outflow Control

Unit Reference	MD-SHE-0282-4520-1000-4520
Design Head (m)	1.000
Design Flow (l/s)	45.2
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	282
Invert Level (m)	98.000
Minimum Outlet Pipe Diameter (mm)	300
Suggested Manhole Diameter (mm)	1800

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	1.000	45.2
Flush-Flo™	0.432	45.1
Kick-Flo®	0.774	40.0
Mean Flow over Head Range	-	36.4

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	8.8	1.200	49.3	3.000	76.8	7.000	116.1
0.200	29.0	1.400	53.1	3.500	82.8	7.500	120.1
0.300	43.9	1.600	56.7	4.000	88.4	8.000	124.0
0.400	45.0	1.800	60.0	4.500	93.6	8.500	127.7
0.500	44.8	2.000	63.1	5.000	98.5	9.000	131.3
0.600	44.0	2.200	66.1	5.500	103.2	9.500	134.8
0.800	40.6	2.400	69.0	6.000	107.7		
1.000	45.2	2.600	71.7	6.500	112.0		

Appendix L

Overland Flows

JPP Consulting drawing no. 11024-FRA06B

General notes

All dimensions are in metres unless otherwise stated.

All levels are in metres.

This drawing is to be read in conjunction with all relevant Engineers and Architect's drawings, Specifications, Reports and Engineering Details.

Do not scale from this drawing.

Based on Topographical Land Survey by SurveyEng Ltd, drawing number BH.TS.12 Rev C dated 26.03.2021.

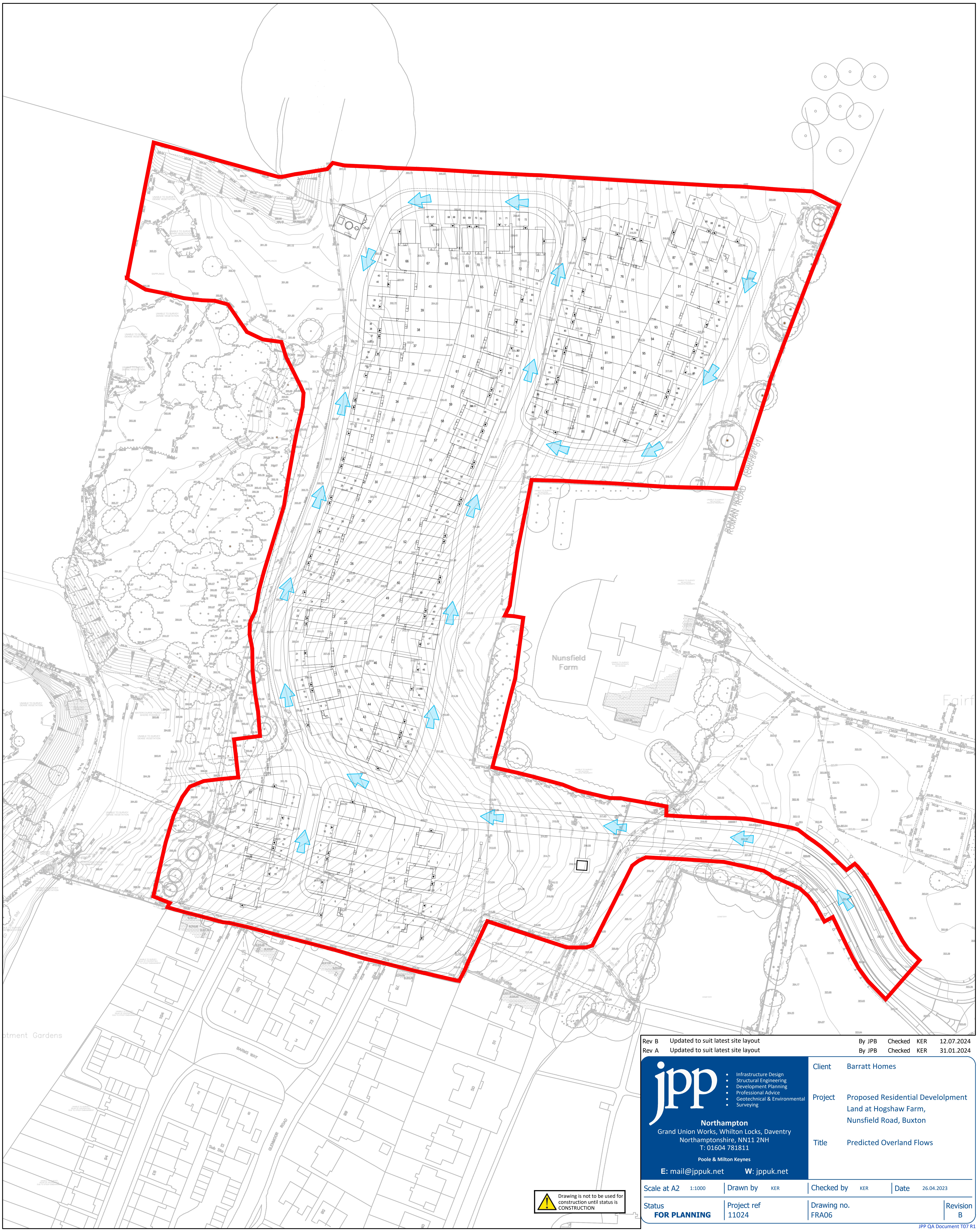
Based on Planning Layout by Barratt Homes, drawing number H8797-BAH-XX-XX-DR-UD-203001-P03 dated 28.06.2024.

Based on Drainage Layout by Barratt Homes, drawing number H8797-BAH-XX-XX-DR-CE-300001-P07 dated 01.07.2024.

Drawing Key

Predicted Overland Flows

Site Boundary



Rev	Description	By	Checked	Date
Rev B	Updated to suit latest site layout	By JPB	Checked KER	12.07.2024
Rev A	Updated to suit latest site layout	By JPB	Checked KER	31.01.2024

jpp

- Infrastructure Design
- Structural Engineering
- Development Planning
- Professional Advice
- Geotechnical & Environmental
- Surveying

Northampton
Grand Union Works, Whilton Locks, Daventry
Northamptonshire, NN11 2NH
T: 01604 781811

Poole & Milton Keynes

E: mail@jppuk.net W: jppuk.net

Client: Barratt Homes

Project: Proposed Residential Development Land at Hogshaw Farm, Nunsfield Road, Buxton

Title: Predicted Overland Flows

Scale at A2: 1:1000	Drawn by: KER	Checked by: KER	Date: 26.04.2023
Status: FOR PLANNING	Project ref: 11024	Drawing no.: FRA06	Revision: B

Drawing is not to be used for construction until status is CONSTRUCTION

Appendix M

Severn Trent Water Pre-Development Enquiry

WONDERFUL ON TAP

Severn Trent Water Ltd
Leicester Water Centre
Gorse Hill
Anstey
Leicester
LE7 7GU

Contact: Emma Nowak
Mob: 07970361864

Email:
Network.Solutions@SevernTrent.co.uk

Our ref: 1080322

JPP Consulting Ltd,
4 Ironstone Way,
Brixworth,
Northampton,
NN6 9UD.

FAO: Katherine Rose

20th April 2023

Dear Katherine,

Proposed Residential Development (116 Residential Dwellings) at: Land at Hogshaw Farm, Nunsfield Road, Buxton

X: 406585 / Y: 374410

I refer to your Development Enquiry Request submitted in respect of the above site. Please find enclosed the sewer records that are included in the fee together with the Supplementary Guidance Notes (SGN) referred to below.

Public Sewers in Site – Required Protection

There are no public sewers crossing the site.

Please Note: On 1st October 2011 many private sewers were transferred into the ownership of Severn Trent Water as public sewers, where two or more properties in separate ownership are served by those sewers. Most of these former private sewers will not be shown on the public sewer records, therefore a full site survey should be carried out prior to any layout design or construction works to identify where these sewers may be and to avoid later delays and possible added costs.

Foul Water Drainage

The most convenient point of connection for gravity foul flows from the site is at the 150mm public foul sewer southwest of the site at the junction of Barms Way & Nunsfield Road. A gravity connection for an additional 116 dwellings (1.8 l/s 2DWF) would be acceptable at this sewer at a new or existing manhole (5203) subject to formal 106 approval.

Please note that a gravity connection should be viable for the whole site, however should after investigations, a pumped connection be required for any part of the site, please notify us as soon as possible further modelling may be required to understand the impact of increased flows in the foul network.

Surface Water Drainage

Under the terms of Section H of the Building Regulations 2000, the disposal of surface water by means of soakaways should be considered as the primary method. If this is not practical a connection to the watercourse southeast of the site would be acceptable subject to LLFA approval. In addition, other sustainable drainage methods should also be explored before a discharge to the public sewerage system is considered.

If these are found to be unsuitable, satisfactory evidence will need to be submitted. The evidence should be either percolation test results or by the submission of a statement from the SI consultant (extract or a supplementary letter).

The site drainage should be discussed with the Local Lead Flood Authority with a view to implement suitable SuDS techniques to land soakaways or other land drainage systems prior to any consideration of discharges to public sewers being accepted. Any discharge rate to a watercourse or drainage ditch will be determined by the LLFA.

Should soakaways / SuDs prove not to be viable, the Nun Brook runs west of the proposed development. A connection to the watercourse should be pursued but may require the crossing of third-party land. Please note, that if you cannot gain consent from the landowner, a S98 Sewer Requisition may be required. For your information, STW have the right to lay sewers through 3rd party land even unregistered land, however, STW do not have the right to discharge to a watercourse/ditch. In order to discharge to a watercourse we require a Deed Of Grant Of Easement (DOGOE) from the watercourse owner. Please liaise with the LLFA as statutory consultee in the planning process to agree flow rates at this location.

No impact on the public network.

WONDERFUL ON TAP

SEVERN TRENT

New Connections

For any new connections including the use, reuse and indirect to the public sewerage system, the developer will need to submit Section 106 application. Our Developer Services department are responsible for handling all such enquiries and applications. To contact them for an application form and associated guidance notes, please call 0800 707 6600, email new.connections@severntrent.co.uk or download from www.stwater.co.uk

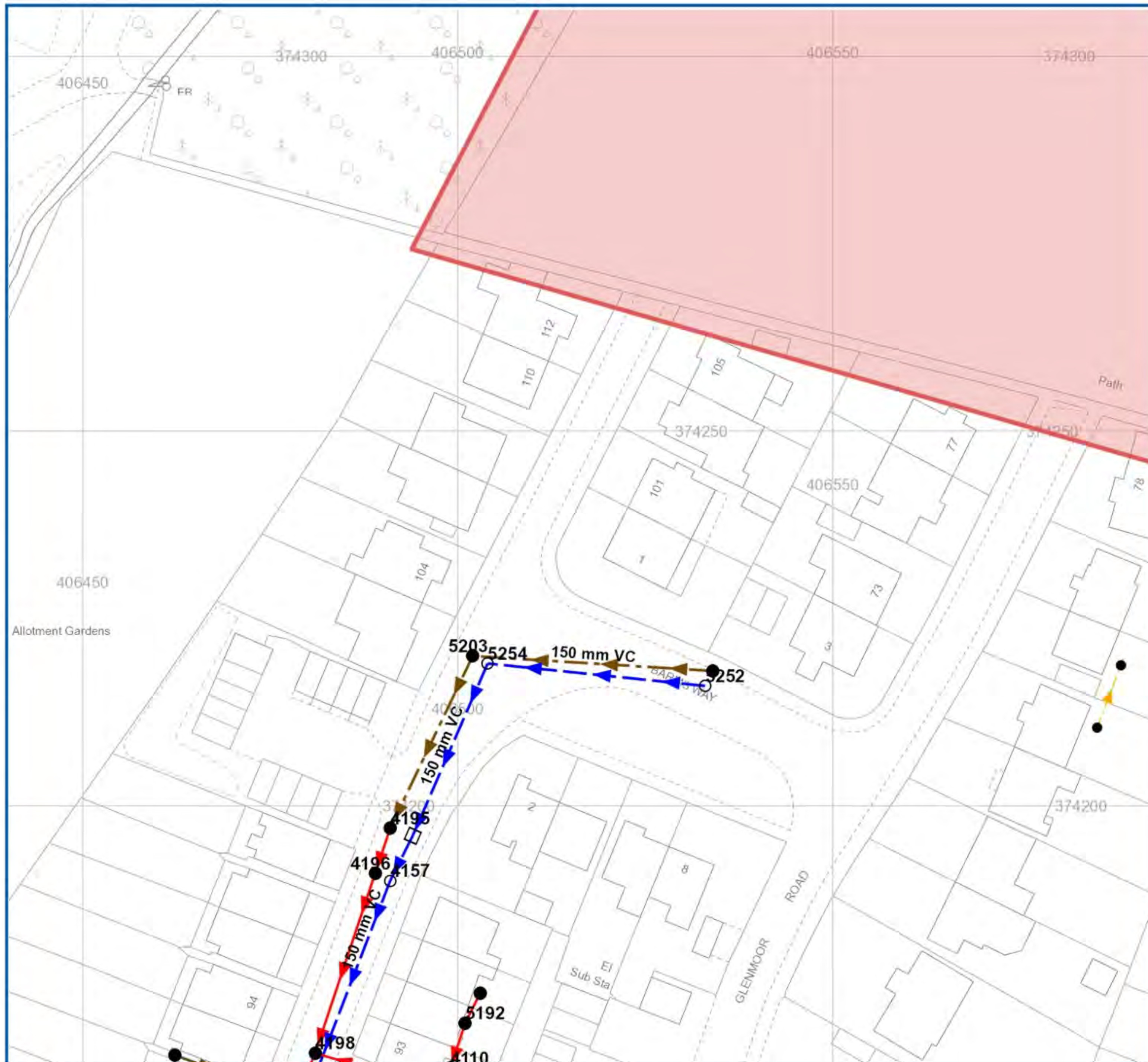
Please quote the above reference number in any future correspondence (including e-mails) with STW Limited. Please send **all correspondence** to the network.solutions@severntrent.co.uk email inbox address, a response will be made within 15 days.

If you require a VAT receipt for the application fee please email MISCINCOME.NC@SEVERNTRENT.CO.UK quoting the above Reference Number.

Please note that Developer Enquiry responses are only valid for 6 months from the date of this letter.

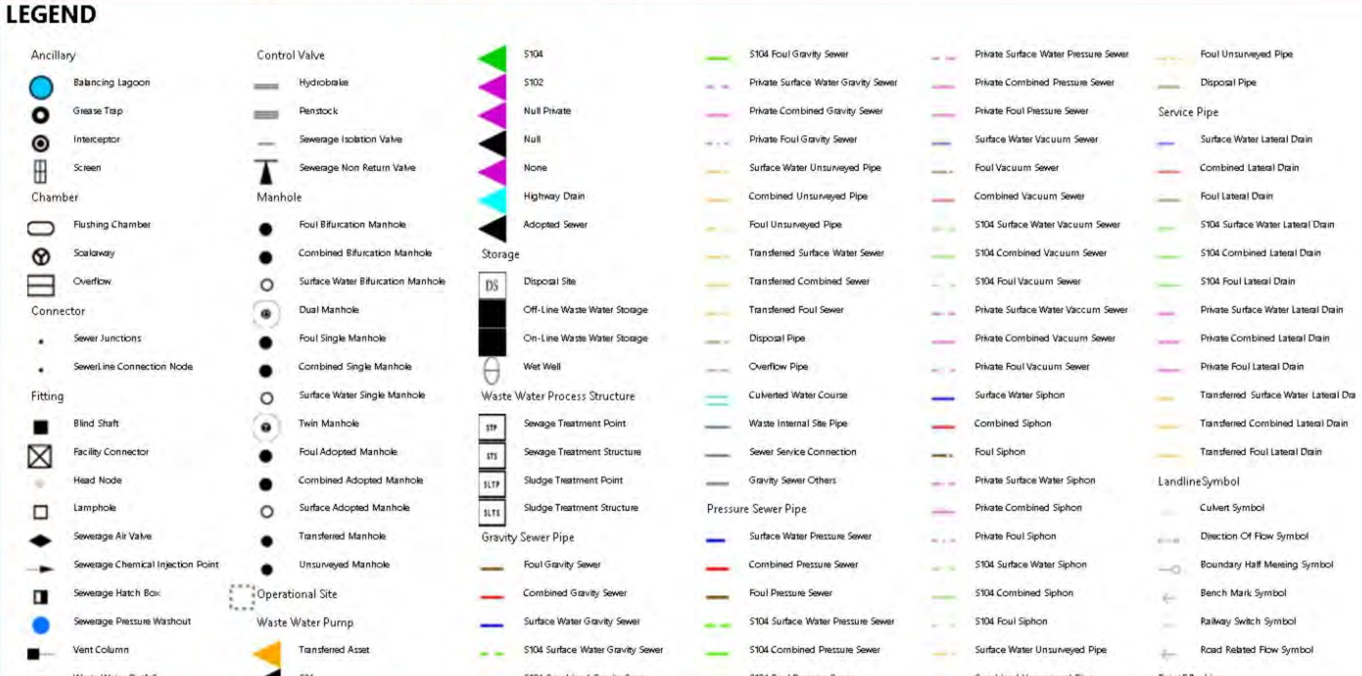
Yours sincerely,

Emma Nowak.
Senior Evaluation Technician
Network Solutions
Developer Services



Reference	Cover Level	Invert Level Upstream	Invert Level Downstream	Purpose	Material	Pipe Shape	Max Size	Min Size	Gradient	Year Laid
SK06745203	306.1759	304.78	303.4	F	VC	C	150	<UNK>	18.48	31/12/1899 00:00:00
SK06745254	306.242	304.93	303.91	S	VC	C	150	<UNK>	24.59	31/12/1899 00:00:00
SK06744196	304.957	<UNK>	300.86	C	VC	C	<UNK>	<UNK>	0	31/12/1899 00:00:00
SK06745201	309.9079	308.58	304.79	F	VC	C	150	<UNK>	8.46	31/12/1899 00:00:00
SK06744195	305.1549	303.4	<UNK>	C	VC	C	150	<UNK>	0	31/12/1899 00:00:00
SK06745191	306.591	305.981	305.746	C	VC	C	100	<UNK>	18.63	31/12/1899 00:00:00
SK06744110	306.3659	305.206	<UNK>	C	VC	C	100	<UNK>	0	31/12/1899 00:00:00
SK06745252	309.9419	308.572	304.94	S	VC	C	150	<UNK>	8.03	31/12/1899 00:00:00
SK06745192	306.436	305.726	305.226	C	VC	C	100	<UNK>	12.64	31/12/1899 00:00:00
SK06744198	304.035	300.84	299.375	C	VC	C	225	<UNK>	33.86	31/12/1899 00:00:00
SK06744157	304.967	303.537	<UNK>	S	VC	C	150	<UNK>	0	31/12/1899 00:00:00
<UNK>	<UNK>	<UNK>	<UNK>	F	VC	<UNK>	<UNK>	<UNK>	<UNK>	05/07/2020 00:00:00
<UNK>	<UNK>	<UNK>	<UNK>	F	VC	<UNK>	<UNK>	<UNK>	<UNK>	14/04/2021 00:00:00

LEGEND



MATERIALS

- \- NONE
- AC - ASBESTOS CEME
- BR - BRICK
- CC - CONCRETE BOX CULVERT
- CI - CAST IRON
- CO - CONCRETE
- CSB - CONCRETE SEGMENTS (BOLTED)
- CSU - CONCRETE SEGMENTS (UNBOLTED)
- DI - DUCTILE IRON
- GRP - GLASS REINFORCED PLASTIC
- MAC - MASONRY IN REGULAR COURSES
- MAR - MASONRY RANDOMLY COURSED
- PE - POLYETHLENE
- PF - PITCH
- PP - POLYPROPYLENE
- PSC - PLASTIC STEEL COMPOSITE
- PVC - POLYVINYL CHLORIDE
- RPM - REINFORCED PLASTIC MATRIX
- SI - SPUN (GREY) IRON
- ST - STEEL
- U - UNKNOWN
- VC - VITRIFIED CLAY
- XXX - OTHER

CATEGORIES

- W - WEIR
- C - CASCADE
- DB - DAMBOARD
- SE - SIDE ENTRY
- FV - FLAP VALVE
- BD - BACK DROP
- S - SIPHON
- D - HIGHWAY DRAIN
- S104 - SECTION 104

SHAPE

- C - CIRCULAR
- E - EGG SHAPED
- O - OTHER
- R - RECTANGLE
- S - SQUARE
- T - TRAPEZOIDAL
- U - UNKNOWN

PURPOSE

- C - COMBINED
- E - FINAL EFFLUENT
- F - FOUL
- L - SLUDGE
- S - SURFACE WATER

SEVERN TRENT

Severn Trent Water Limited
Asset Data Management
PO Box 5344
Coventry
CV3 9FT
Telephone: 0345 601 6616

SEWER RECORD (Tabular)

O/S Map Scale: 1:750

Date of Issue: 20-04-23

This map is centred upon:

X: 406516.49 **Y:** 374235.53

Disclaimer Statement:

1 Do not scale off this Map.

2 This plan and any information supplied with it is furnished as a general guide, is only valid at the date of issue and no warranty as to its correctness is given or implied. In particular this plan and any information shown on it must not be relied upon in the event of any development or works (including but not limited to excavations) in the vicinity of SEVERN TRENT WATER assets or for the purposes of determining the suitability of a point of connection to the sewerage or distribution systems.

3 On 1 October 2011 most private sewers and private lateral drains in Severn Trent Water's sewerage area, which were connected to a public sewer as at 1 July 2011, transferred to the ownership of Severn Trent Water and became public sewers and public lateral drains. A further transfer takes place on 1 October 2012. Private pumping stations, which form part of these sewers or lateral drains, will transfer to ownership of Severn Trent Water on or before 1 October 2016. Severn Trent Water does not possess complete records of these assets. These assets may not be displayed on the map.

5 Ordnance Survey licence number: **100031673**

Appendix N

Hydraulic Modelling Report

JBA Technical Note 2023s1142

TECHNICAL NOTE

JBA Project Code	2023s1142
Contract	Hydraulic Modelling at Hogshaw Farm
Client	Barratt Homes Manchester
Date	January 2024
Author	Ella Albrighton BSc
Reviewer / Sign-off	Amy Evans BSc MCIWEM C.WEM
Subject	Hydraulic Modelling at Hogshaw Farm, Buxton

1 Introduction

1.1 Terms of reference

JBA Consulting were commissioned by JPP Consulting Ltd on behalf of Barratt Homes Manchester to undertake a fluvial hydraulic modelling study in order to support their planning application for a proposed development at their site at Hogshaw Farm, Buxton.

The Nun Brook, which becomes an Environment Agency Main River downstream of the site, flows in a southerly direction through the north-western part of the site. The watercourse is culverted during this reach. The culvert has a diameter of 1.22m. The location of the site and the Nun Brook are included within Figure 1-1 below.

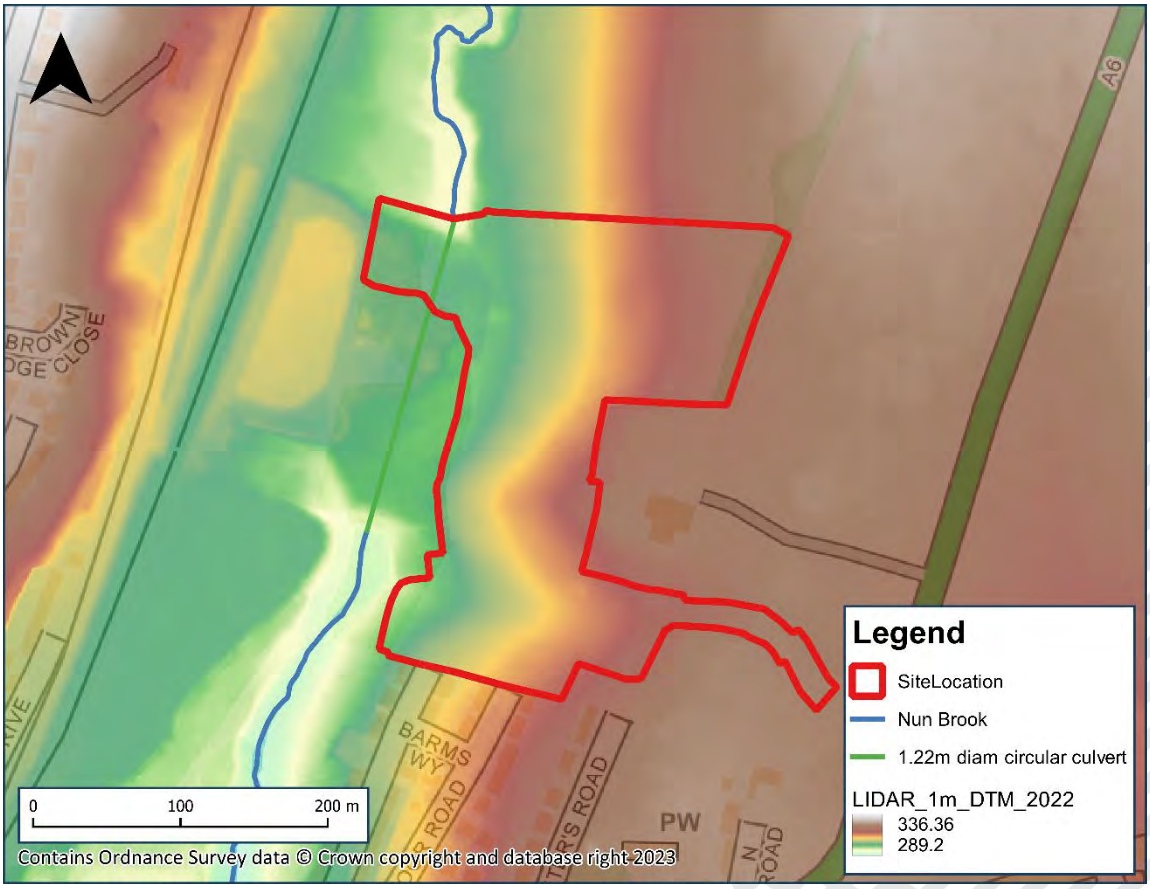


Figure 1-1 - Site Location

2 Baseline Hydraulic modelling

2.1 Modelling Approach

A license to re-use the 1D-2D ESTRY-TUFLOW 2022 Hogshaw and Nun Brook hydraulic model was obtained from the Environment Agency for use in this study. The hydrology inflows, calculated in 2022 as part of the original modelling, were retained as these still reflect best practises.

The extent of the existing model in relation to the site is shown within Figure 2-1 below.

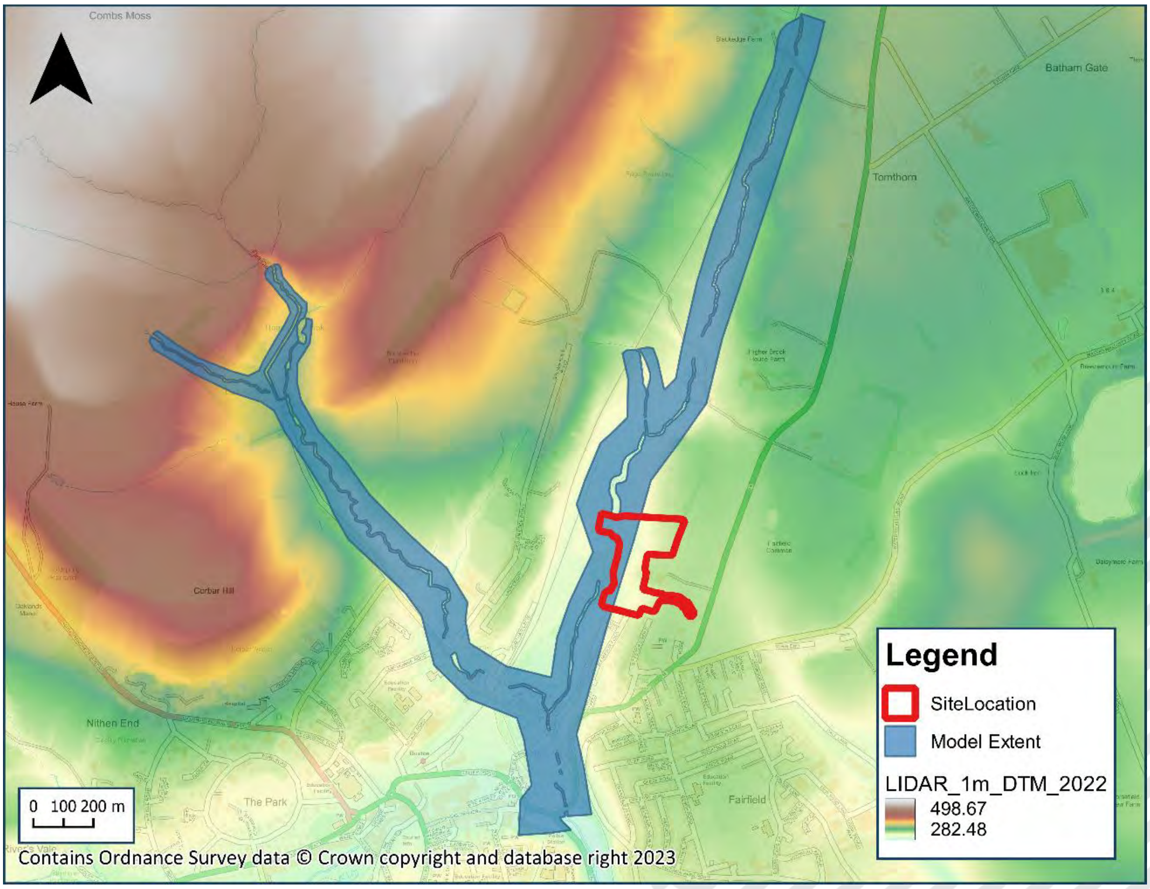


Figure 2-1: Existing model extent

New topographic survey data (included within Appendix A) representing the current ground levels within the site was integrated within the model.

The updated and refined baseline model was run with TUFLOW version 2023-03-AA-iDP-w64 for the 30-year, 100-year, 100-year with climate change (29%) and 1000-year fluvial flood events.

2.2 Baseline model results

2.2.1 Baseline flood extents

The baseline flood extents during the 30-year, 100-year and 1000-year events are shown in Figure 2-2 below. Figure 2-3 shows the impact of climate change on the 100-year flood extents.

This shows that only the north-western area of the site is included with the maximum flood extent during all of the modelled flood extents.

Figure 2-3 shows that, when 29% climate change is applied to the 100-year event, there is no impact on flood extents within the site. Upstream of the site, there is a slight increase in flood extent.

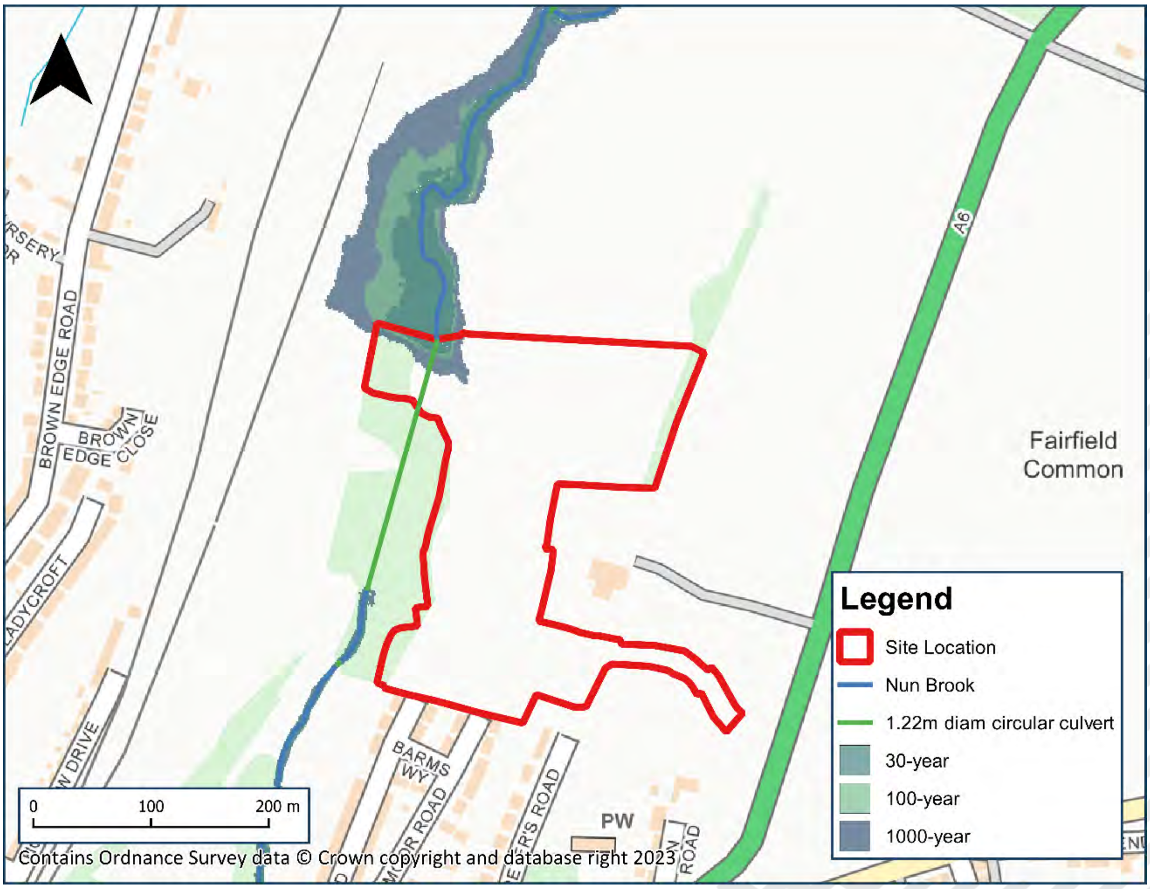


Figure 2-2: Baseline flood extents

JBA Project Code	2023s1142
Contract	Hydraulic Modelling at Hogshaw Farm
Client	Barratt Homes Manchester
Date	January 2024
Author	Ella Albrighton BSc
Reviewer / Sign-off	Amy Evans BSc MCIWEM C.WEM
Subject	Hydraulic Modelling at Hogshaw Farm, Buxton

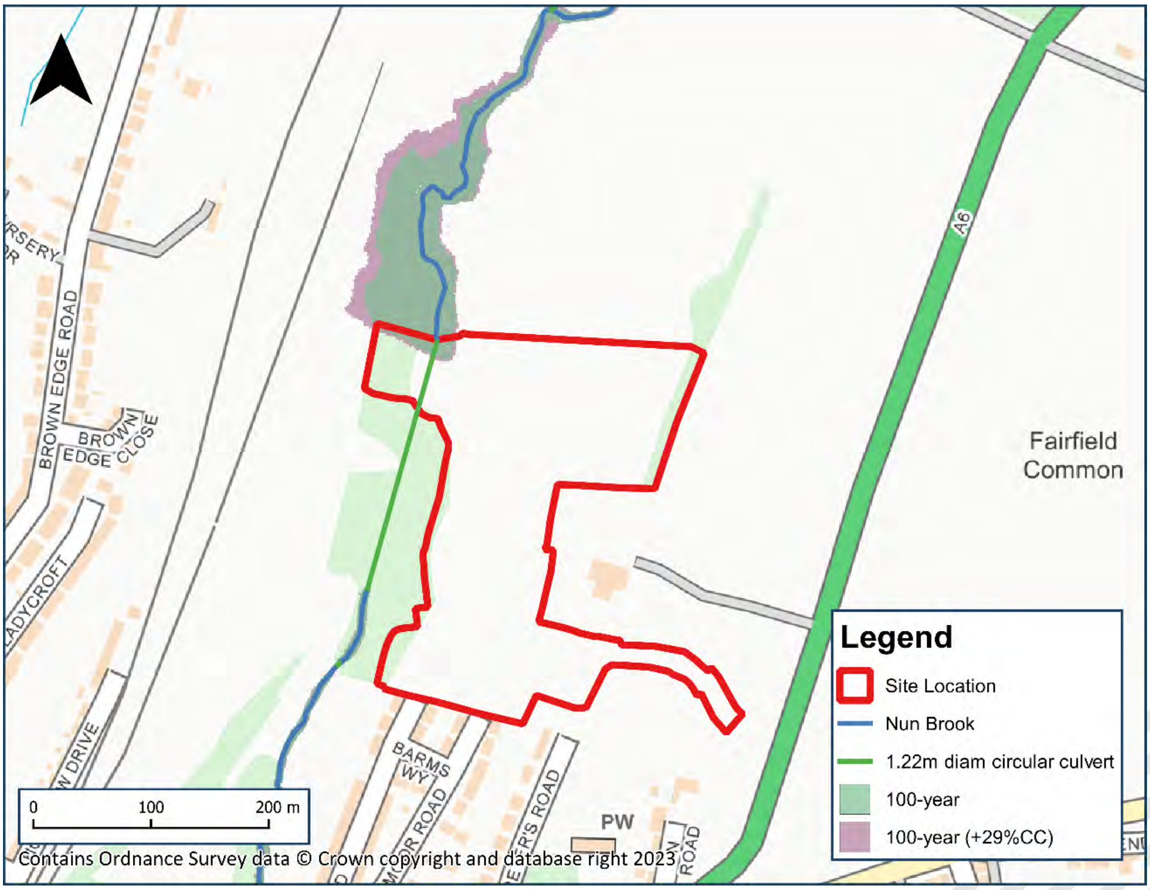


Figure 2-3: Baseline flood extent with climate change

2.2.2 Baseline flood depths

The flood depths within the site during the 100-year with 29% climate change flood event (i.e. the design event) are shown within Figure 2-4.

This shows that within the site, the maximum flood depths are upstream of the 1.22m diameter culvert inlet. The maximum flood depth in this area is 4.02m, within the area of low elevation surrounding the channel.

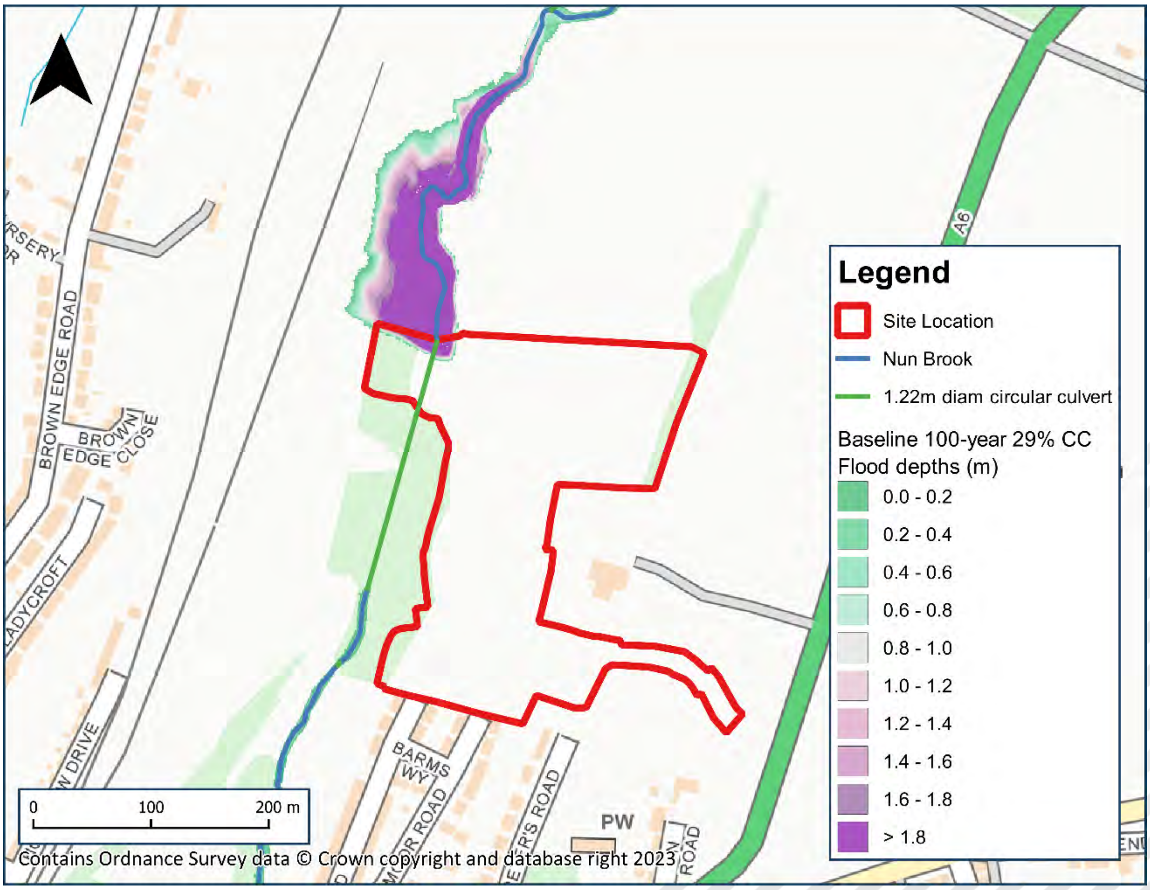


Figure 2-4: Baseline flood depths

JBA Project Code	2023s1142
Contract	Hydraulic Modelling at Hogshaw Farm
Client	Barratt Homes Manchester
Date	January 2024
Author	Ella Albrighton BSc
Reviewer / Sign-off	Amy Evans BSc MCIWEM C.WEM
Subject	Hydraulic Modelling at Hogshaw Farm, Buxton

2.2.3 Baseline water levels

The water levels during the baseline 100-year with 29% climate change are shown in Figure 2-5. During the baseline 100-year with 29% climate change event, the peak water level onsite and at the inlet of the culvert is 299.90m AOD.

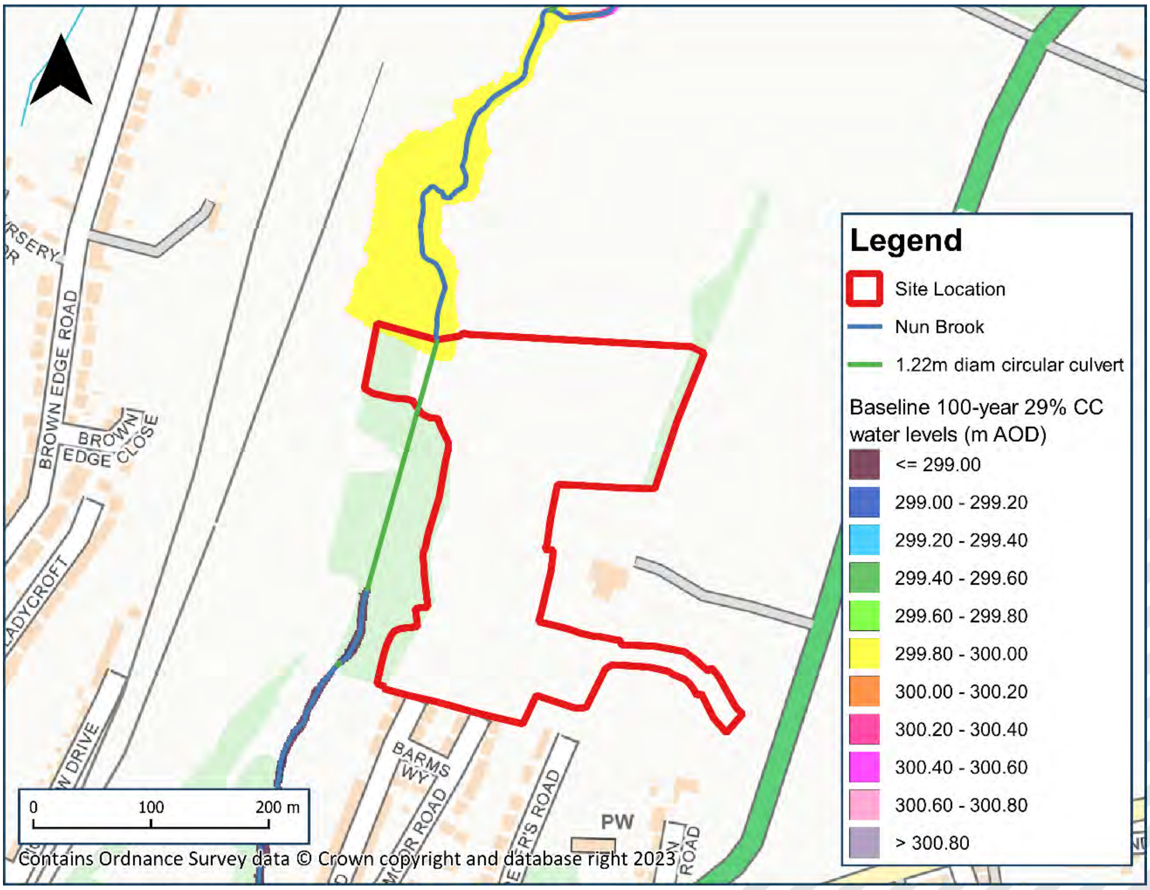


Figure 2-5: Baseline water levels

2.2.4 Baseline hazard to people

The fluvial hazard-to-people rating during a 100-year with 29% climate change flood scenario has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 2-1 and the hazard classification to the site during the 100-year with 29% climate change scenario is shown in Figure 2-6.

Table 2-1 Flood Risk to People Hazard to People

Flood hazard rating depth x (velocity+0.5) +DF	Level of Flood Hazard Description	Class label
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 to 1.25	Moderate	Dangerous for some (i.e. Children) "Danger: flood zone with deep or fast flowing water"
1.25 to 2.00	Significant	Danger for most "Danger: flood zone with deep fast flowing water"
>2.00	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"
Using the hazard equation HR = d*(v+0.5) + DF Where d = depth of flooding (m) v = velocity of floodwaters (m/sec) DF = debris factor		

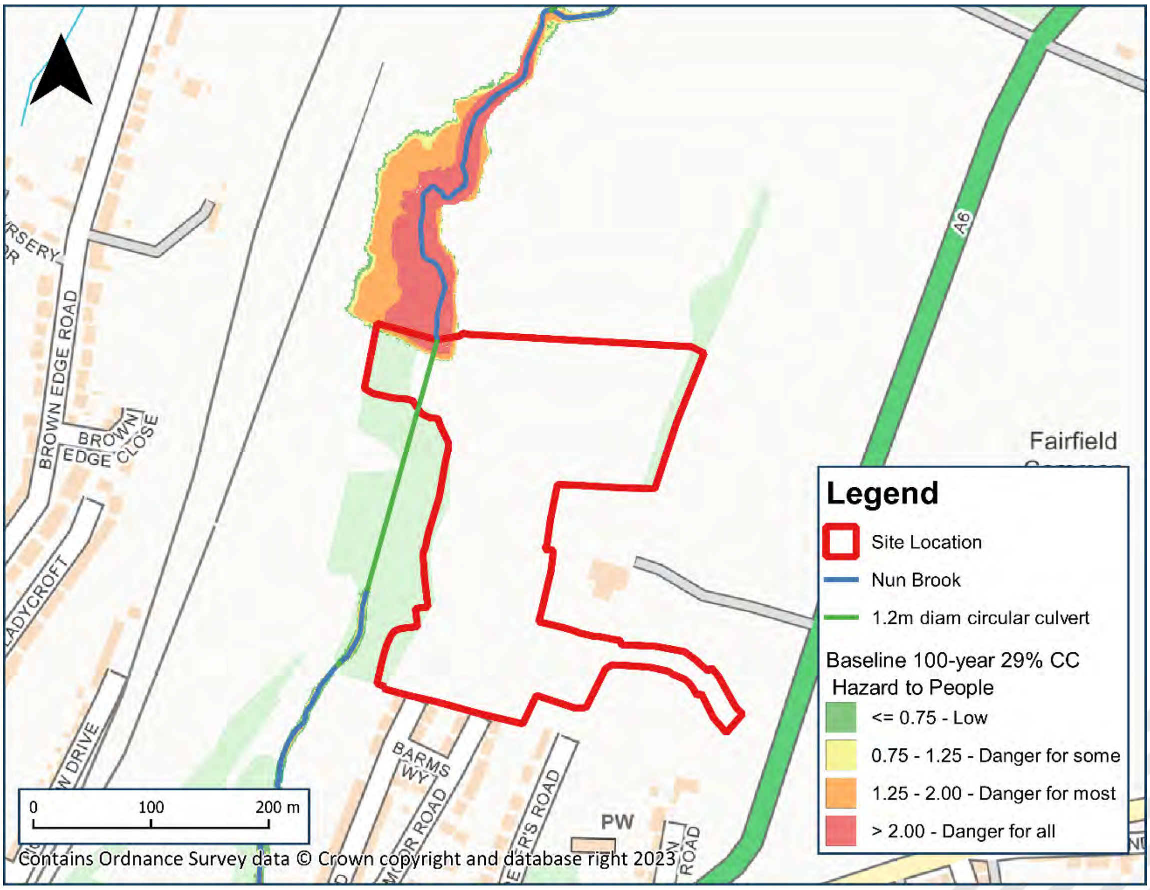


Figure 2-6: Baseline hazard to people

Figure 2-6 shows that during the baseline 100-year with 29% climate change event the north-western area of the site is partially within the 'danger for all' hazard category. However, this is primarily the channel and immediate floodplain of the Nun Brook.

2.3 Blockage analysis

The residual risk of a blockage at the inlet of the 1.22m diameter culvert has been considered as part of this study. In order to represent the worst-case scenario a 100% blockage at the structure has been modelled. Figure 2-7 shows the maximum flood extent during the 100% blockage at the structure during a 100-year with 29% climate change flood event. This shows that the flood extent is larger during this event where flows build up behind the inlet before eventually flowing overland to the downstream culvert extent where the Nun Brook becomes open channel.

Figure 2-8 shows the peak water levels associated with this residual event.

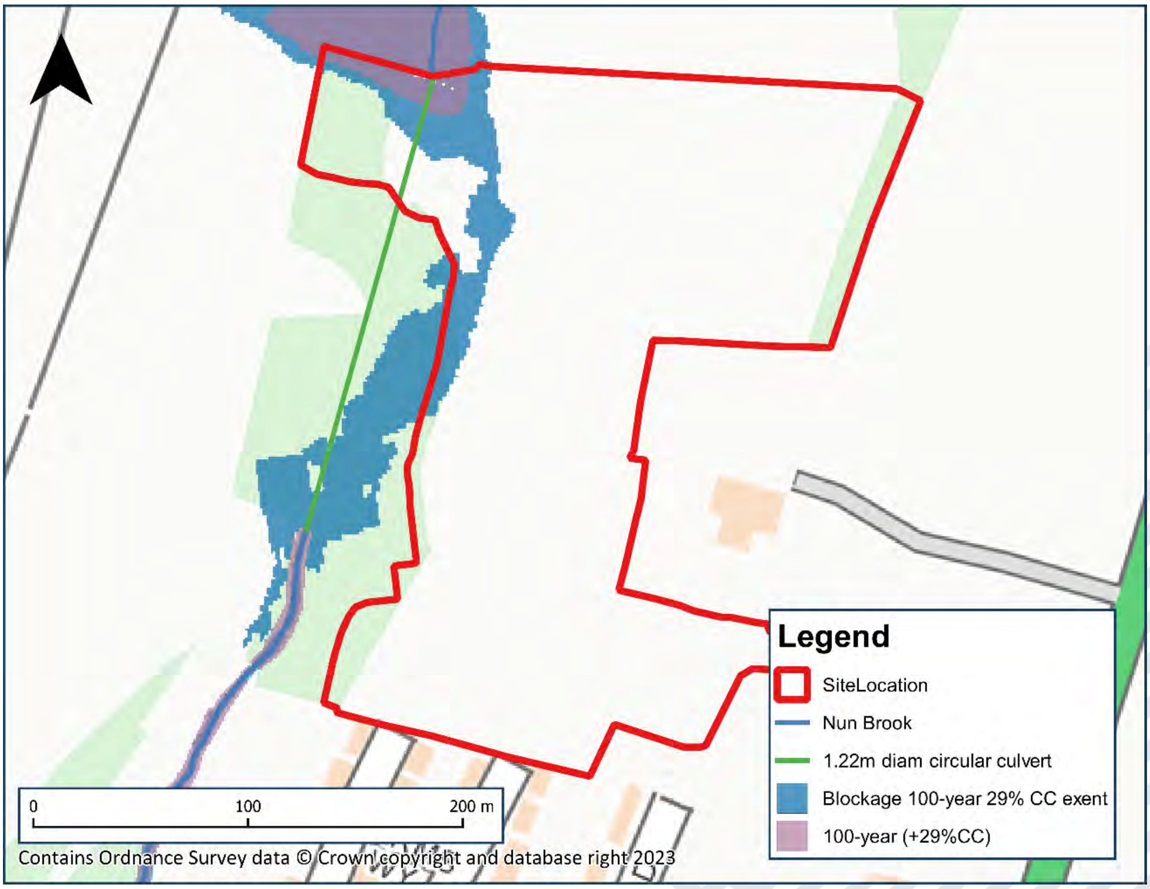


Figure 2-7: Blockage extent

JBA Project Code	2023s1142
Contract	Hydraulic Modelling at Hogshaw Farm
Client	Barratt Homes Manchester
Date	January 2024
Author	Ella Albrighton BSc
Reviewer / Sign-off	Amy Evans BSc MCIWEM C.WEM
Subject	Hydraulic Modelling at Hogshaw Farm, Buxton

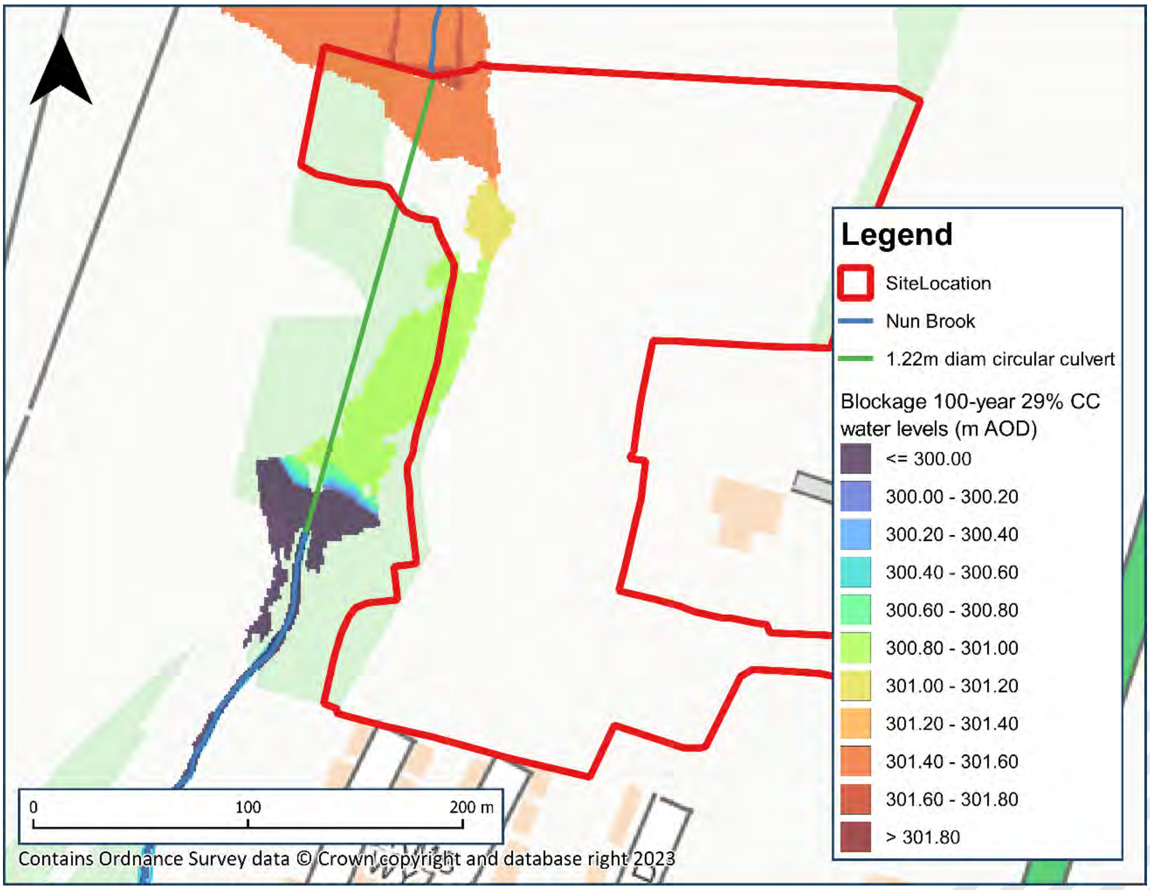


Figure 2-8: Blockage water levels

Figure 2-8 shows that during the 100-year with 29% climate change flood event with a 100% culvert blockage, the modelled peak water level is 301.78m AOD in the north-western area of the site. This is a 1.88m increase in peak water level compared to the baseline scenario.

3 On-site Surface Water Discharge Hydraulic Modelling

3.1 Modelling Approach

In order to assess the impact of the surface water drainage scheme proposed as part of the development, an assessment of the pre- and post- on-site surface water flows was completed using the baseline modelling described in Section 3.

3.2 Revised baseline reflecting current greenfield runoff flows

The existing greenfield run-off rates have been calculated as part of the proposed drainage strategy produced for the site by JPP Consulting. Appendix I of their report states that the peak greenfield runoff rate for the site for the 100-year rainfall event is 116.2 l/s. For the revised baseline scenario, this has been converted into m^3/s and read into the model as a lateral constant flow downstream of the 1.22m diameter culvert, inline with the ground levels within the site. In order to account for climate change, this inflow has been increased by 40%.

Applying the greenfield runoff from the site directly as a point inflow is a conservative approach as the existing model hydrology will account for the site runoff. Also, in reality, the flow would exhibit a hydrograph shape and would not be a constant. However, it was considered necessary to apply this to the baseline as the proposed drainage strategy discharge is to be applied to the post developed model scenario in a similar way.

The revised baseline model scenario was then run for the 100-year 29% climate change event.

3.3 Post-developed model reflecting the proposed on-site surface water outfall

The principal of the proposed drainage strategy for the development is for the whole site to drain to the watercourse, upstream of the 1.22m culvert via an attenuation basin. Discharge from the site into the watercourse will be restricted to 45.2l/s during the 100-year plus climate change (40%) rainfall event. In order to represent the impact of the proposed surface water discharge within the site, this has been modelled in a post-development model scenario.

During the post-development scenario, the proposed peak discharge (45.2l/s) has been applied as a constant flow upstream of the culvert as a lateral inflow to the watercourse. Note that this is conservative as in reality the flow would exhibit a flattened peak hydrography shape. The hydrology from the remaining model remains as per the baseline modelling but the greenfield runoff rate inflow applied to the revised baseline was excluded.

The post developed model scenario was then run for the 100-year 29% climate change event.

3.4 On-site Surface Water Discharge Hydraulic Modelling - Revised Baseline and Post-developed results

The results from the revised baseline modelling and post-development modelling were compared. The impact of the post-developed surface water drainage strategy on downstream flood extents is shown in Figure 3-1 below.

This shows that, with the proposed drainage strategy in place, there is a slight reduction in the flood extent downstream of the site as a greater proportion of the flow is held upstream of the 1.22m culvert. Figure 3-2 below shows the impact on flood depths during the 100-year with climate change event. It shows that there is a reduction in the flood depths downstream within the north-eastern area of Buxton. There is an increase in flood depths upstream of the site of up to 0.05m, however, the extent is unchanged.

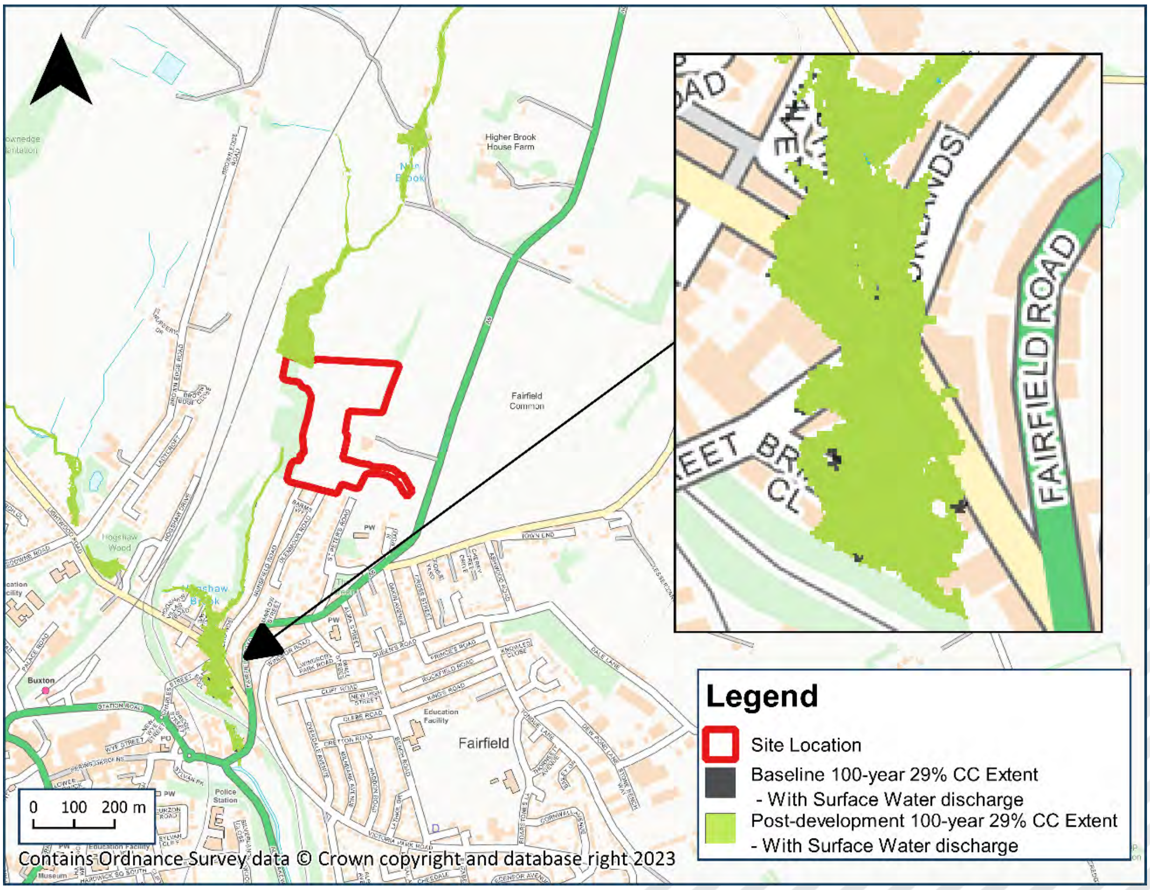


Figure 3-1: Impact on flood extents from surface water discharge amendment

JBA Project Code	2023s1142
Contract	Hydraulic Modelling at Hogshaw Farm
Client	Barratt Homes Manchester
Date	January 2024
Author	Ella Albrighton BSc
Reviewer / Sign-off	Amy Evans BSc MCIWEM C.WEM
Subject	Hydraulic Modelling at Hogshaw Farm, Buxton

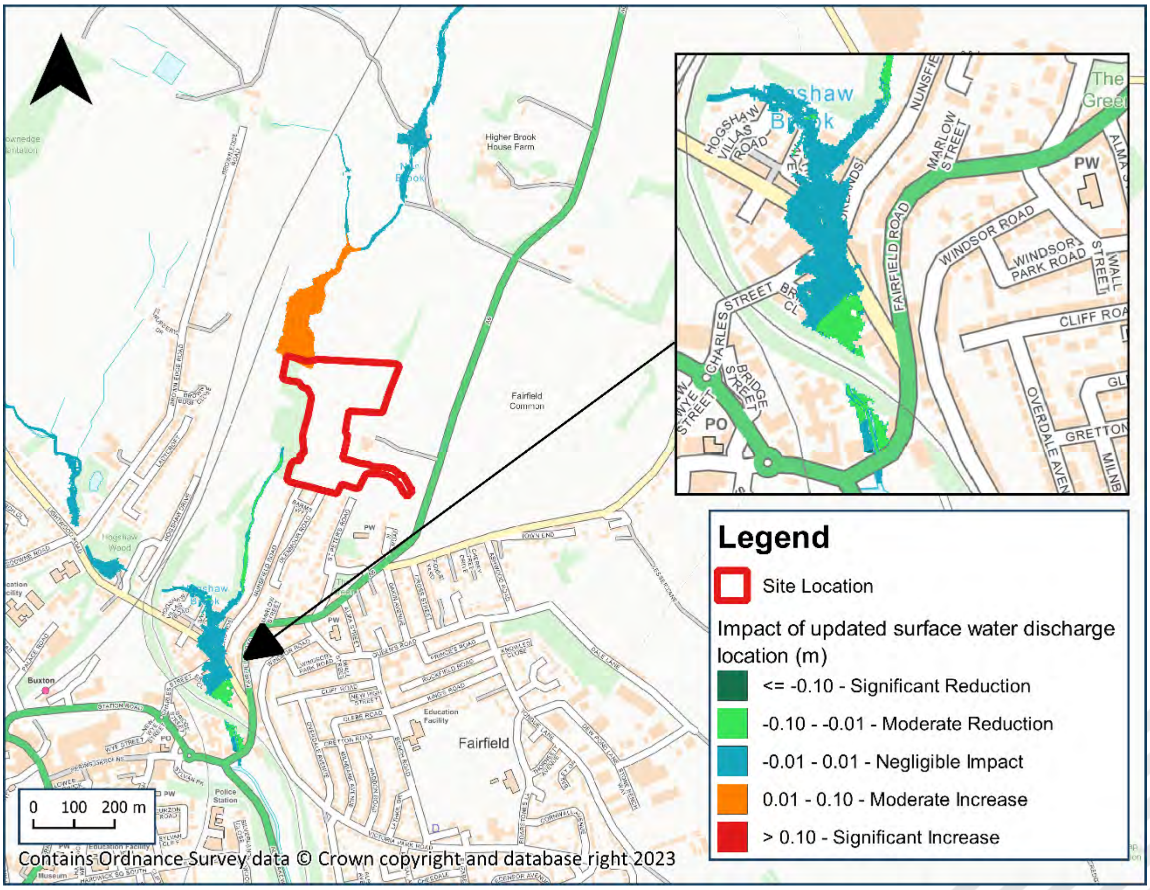


Figure 3-2: Impact on flood depths from surface water discharge amendment

4 Conclusion

- JBA Consulting were commissioned by JPP Consulting Ltd on behalf of Barratt Homes Manchester to undertake a fluvial hydraulic modelling study in order to support their planning application for a proposed development at their site at Hogshaw Farm, Buxton.
- The Nun Brook flows in a southerly direction through the north-western part of the site. The watercourse is culverted during this reach.
- A license to re-use the 1D-2D ESTRY-TUFLOW 2022 Hogshaw and Nun Brook hydraulic model was obtained from the Environment Agency for use in this study. The hydrology inflows, calculated in 2022 as part of the original modelling, were retained as these still reflect best practises.
- New topographic survey data representing the current ground levels within the site was integrated within the model.
- The updated and refined model was run with TUFLOW version 2023-03-AA-iDP-w64 for the 30-year, 100-year, 100-year with climate change (29%) and 1000-year fluvial flood events.
- Baseline model results show:
  - only the north-western area of the site is included with the maximum flood extent during all of the modelled flood extents. Model results show when 29% climate change is applied to the 100-year event, there is no impact on flood extents within the site. Upstream of the site, there is a slight increase in flood extent.
  - Within the site, the maximum flood depths can be found along the north-eastern area of the site upstream of the 1.22m diameter culvert. The maximum flood depth in this area is 4.02m.
  - During the baseline 100-year with 29% climate change event, the peak water levels is 299.90m AOD within the site.
  - The north-eastern areas of the site during the baseline 100-year with 29% climate change event the site is partially within the 'danger for all' hazard category.
- To represent the worst-case scenario, a 100% blockage at the 1.22m diameter culvert has been modelled for the 100-year with 29% climate change event. The blockage model results show that:
  - The flood extent is larger during this event where flows build up behind the culvert inlet before eventually flowing overland to the downstream culvert extent where the Nun Brook becomes open channel.
  - Within the site, during a 100% culvert blockage scenario, the peak water level will be 301.78m AOD in the north-western part of the site.
- In order to assess the impact of the surface water drainage scheme proposed as part of the development, an assessment of the pre- and post- on-site surface water flows was completed.
  - The existing greenfield run-off rates have been calculated as part of the drainage strategy produced for the site. A revised baseline model scenario was

set up which includes a lateral flow into the model to represent the greenfield 1 in 100 year plus climate change peak runoff (116.2 l/s). A review of ground levels within the site shows that the majority of this greenfield flow would enter the Nun Brook downstream of the 1.22m diameter culvert and therefore, this is where the lateral inflow has been applied for the revised baseline model scenario.

- During the post-development scenario, the proposed drainage strategy was represented by applying a lateral inflow at the proposed attenuated rate of 45.2l/s. In line with the proposed strategy, the lateral inflow in the post-developed model was applied upstream of the 1.22m.
- The pre- and post- on-site surface water modelling result show:
  - With the proposed drainage strategy in place, there is a slight reduction in the flood extent downstream of the site.
  - There is a reduction in the flood depths downstream within the north-eastern area of Buxton. There is an increase in flood depths upstream of the site of up to 0.05m however, the extent is unchanged.

Appendix B
Site Investigation

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Proposed residential development
Land off Nunsfield Road
Buxton

Ground Investigation Report

Revision 03

Unit 9, Clarence Avenue, Westpoint Enterprise Park, Trafford Park, Manchester, M17 1QS
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Proposed residential development land off Nunsfield Road Fairfield Buxton Derbyshire SK17 7HN

GROUND INVESTIGATION REPORT

Revision 03 – updated April 2023

Soiltechnics Ltd. Unit 9, Clarence Avenue, Westpoint Enterprise Park, Trafford Park, Manchester, M17 1QS
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Reviewed by	Sam Dean B.Sc. (Hons)., MIEnvSc., FGS	sam.dean@soiltechnics.net Director

Updates from Rev00 to Rev01 are marked by a vertical solid line in the left-hand margin.

Updates from Rev01 to Rev02 are marked by a vertical dashed line in the left-hand margin.

Updates from Rev02 to Rev03 are marked by a vertical dashed line in the left-hand margin.

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Aerial photograph of site

Approximate site boundaries edged in **magenta**.
Area denoted in red (area formerly referred to as Zone 1) now excluded from developable site

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Bookmarking

As a PDF version this document is bookmarked. If you click on the bookmark icon on a PDF viewer then the main contents listing is shown and by clicking on the bookmark you can navigate through the report.

Report status and format

Report section	Principal coverage	Report status	
		Revision	Comments
1	Executive summary	Rev03	Updated April 2023
2	Introduction	Rev03	Updated April 2023
3	Desk study information and site observations	Rev02	Updated August 2019
4	Fieldwork	Rev01	Updated June 2019
5	Laboratory testing	Rev01	Updated June 2019
6	Ground conditions encountered	Rev01	Updated June 2019
7	Geotechnical Appraisal	Rev03	Updated April 2023
8	Chemical contamination	Rev02	Updated August 2019
9	Gaseous contamination	Rev02	Updated August 2019
10	Effects of ground conditions on building materials	Rev02	Updated August 2019
11	Landfill issues		
12	Further investigations	Rev02	Updated August 2019
13	Remediation strategy and specification	Rev02	Updated August 2019

List of drawings

Drawing	Principal coverage	Status	
		Revision	Comments
01	Site location plan	Rev 01	Updated June 2019
02	Plan showing existing site features and location of exploratory points	Rev 01	Updated June 2019
03	Plan showing development proposals and location of exploratory points	Rev 02	Updated August 2019
04	Plan showing development proposals, location of exploratory points and zonal assessment	Rev 02	Updated August 2019
05a-05c	Plans showing depths to bedrock and extent of proposed cut into bedrock across the site	Rev 02	Only 05c updated August 2019
06a-06f	Plot summarising pocket penetrometer determinations	Rev 01	Updated June 2019
07a-07f	Plot summarising Standard Penetration Test (SPT) results	Rev 01	Updated June 2019
08	Section showing construction of combined water & gas monitoring standpipe installed in boreholes	Rev 01	Updated June 2019
09	Preliminary foundation zoning plan	Rev 02	Updated August 2019

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List of appendices

Appendix	Content		Status	
			Revision	Comments
A	Definitions of geotechnical terms used in this report			
B	Definitions of geo-environmental terms used in this report			
C1	Insitu testing in boreholes / trial pits	Details of standard penetration tests (SPT)	Rev01	Updated June 2019
C2		Details of insitu shear strength determinations	Rev01	Updated June 2019
C3		Results of infiltration testing in boreholes	Rev01	Updated June 2019
D	Trial pit records			
E	Boreholes records			
F	Photographic records of the site			
G	Copies of laboratory test result certificates - Soil classification testing			
H	Copies of laboratory test result certificates - Concentrations of chemical contaminants			
I	Analysis and summary of test data in relation to concentrations of chemical contaminants		Rev02	Updated August 2019
J	Conceptual models for chemical contamination		Rev02	Updated August 2019
K	Record of in-situ gas monitoring results		Rev02	Updated August 2019
L	Copies of statutory undertakers' replies			
M	Copy of desk study information produced by Envirocheck			
N	Copy of cut and fill plan		Rev02	Updated August 2019
O	Current development t layout			

1 Executive summary

General

We recommend the following executive summary is not read in isolation to the main report which follows.

Site description, history and development proposals

The site is positioned in the north-eastern part of Buxton, Derbyshire, approximately 700m from the town centre and located along the eastern and western flanks of Nuns Brook. The site is approximately 21Ha in size and formed of a series of distinct parcels of land, largely unoccupied and covered in vegetation and woodland, in addition to some grazing/pasture land. A recreational ground and play area was located to the south of the site, with areas of tended landscaping located to the east. Surface levels in the eastern part of the site fall significantly from east to west down to the channel of Nun Brook, by some 20-23m. Similarly, levels in the western part of the site fall by some 5m from west to east again into the channel of Nun Brook.

Historically, the north-western part of site was open land until a refuse tip was recorded between 1967 and 1988. The eastern part of the site was used as agricultural land with Russia Mere (a pond) recorded between 1879 and 1967. The western part was used for various activities including a railway line with sidings including an engine shed (1898 to 1974), in addition to allotment gardens (1922 to 1967) and playing fields to the south (1977 to present day).

We understand the scheme will comprise the construction of a large number of dwellings, together with associated gardens, infrastructure and access roads constructed to standards allowing adoption by the local highway authority.

Ground conditions encountered

Topsoil was encountered across Zone 3 and partly within Zone 4. Within Zone 2, Made Ground was encountered, locally consistent with landfill type material (within the area of the existing recreation ground to the south, recorded as a tip by the LA) encountered in Zone 1 previously, but including increased quantities of slag, brick, coal, glass and ash. Such deposits ranged to between depths of 3.0m to >5m to the east and south, with deposits ranging between 0.8m to 1.5m to the northwest of the area. Similar deposits were encountered locally across Zone 4. Natural strata was encountered in all locations. This comprised bedrock deposits, which had generally weathered into gravels, sands and clays from their parent units of Bee Low Limestone Formation (Zone 4), Eyam Limestone Formation (Zone 3 and east of Zone 2) and Weathered Bowland Shale Formation (Zone 2 and western parts of Zone 3).

Further details on ground conditions are provided in Section 6.

Foundation solution

In our opinion naturally deposited weathered bedrock will adequately support proposed buildings on concrete strip/trench fill foundations in Zone 3 and localised areas of Zones 2 and 4. Foundations are likely to require depending in some areas due to the presence of Made Ground or natural soils with low strength/density.

Some areas of land to the west of Nun Brook (former railway land, termed Zone 2) contains deep Made Ground which will be unsuitable for supporting concentrated foundation loads. We do not consider such deposits amenable to improvement techniques such as vibrotreatment (unless screened and sorted), and therefore in our opinion a piled foundation solution will be necessary.

We would recommend that further intrusive investigations are undertaken to confirm foundation requirements on a plot specific basis once development proposals are finalised.

In addition, consideration will need to be given to the requirement for use of breaking equipment to facilitate earthworks and foundation excavations where shallow bedrock is present (Zone 3), in addition to stability of slopes in such areas.

Limestone bedrock in Zones 3 and 4 may be susceptible to formation of dissolution features, and further investigation should be undertaken to determine the risk to the proposed development.

Ground bearing floor slabs can be adopted in Zone 3 at this site where buildings are remote from trees and where Topsoil deposits are fully removed within the footprint of the building. Due to the thickness of Made Ground deposits present in Zone 2 (unless proposed cut removes all Made Ground) and the likelihood that Made Ground or reworked soils are present in Zone 4 in the area of Plots 1 to 12, we recommend a suspended ground floor is adopted.

Concrete in contact with Made Ground will need to be designed to sulphate class DS-3 and ACEC class AC-3. Naturally deposited soils and groundwater would be classified as DS-1 AC-1.

Further details are provided in Section 7.

Chemical and gaseous contamination

Providing the site is developed then the risk of harm being caused to current users from identified contamination will be a short-term issue and unlikely to require any remediation.

Concentrations of chemical contaminants have been measured above guideline values within Made Ground deposits across the site. In such areas, we are of the opinion that the site represents a medium to high risk of causing harm to future end users of the developed site, based on current development proposals. Providing the remedial measures as outlined in Section 8.9 and 13 are implemented, the risk of harm being caused to the health of end users is considered to be low.

We also consider that Topsoil/naturally deposited soils at the site are unlikely to cause significant harm to human health and can be reused within the proposed development where necessary.

The risk of damage to the health of construction operatives and other site investigators is, in our opinion, medium but locally high, primarily due to the presence of asbestos in Made Ground soils. Generally, risks would be minimised by taking adequate hygiene precautions on site, however, consideration will need to be given to the presence of localised asbestos in Made Ground soils onsite and the additional precautions that will need to be taken during groundworks to minimise contact/disturbance and potential release of fibres.

Marginally elevated concentrations of leachable benzo(a)pyrene and copper have been previously been identified in Made Ground soils in Zone 1 (landfill area), with very marginal concentrations of soluble copper identified in groundwater onsite and surface waters downstream of site. Given the marginal exceedances of soluble copper and based on the conservatism factored into the EQS value for copper, we consider the risk of leachable copper, identified in the landfill area adjacent to the developable site, adversely impacting the quality of groundwater and surface waters is low.

In our opinion, marginal contamination identified in Topsoil/natural soils across the site is unlikely to present a risk of causing significant harm to vegetation. Concentrations of contaminants exceed relevant guidelines within Made Ground deposits across the site. In our opinion, such contamination is likely to present a risk of causing significant harm to vegetation. Providing the remedial measures as outlined Section 8.9 and 13 are implemented, the risk of harm being caused to the health of vegetation is considered to be low.

In the area of Zone 2, the development will require gas protective measures which would achieve a '*gas protection score'* of 3.5. Furthermore, with such areas of the site being classified as 'Amber 1', then following NHBC report No 10627-R01(04) table 14.2, 'low level' gas protection measures are required as minimum. We recommend that this is verified by completion of further, more intensive ground gas monitoring to fully classify this area of the site.

The area of Zones 3 and 4 are unlikely to require any gas protective measures. However, we recommend that this is verified by completion of further, more intensive ground gas monitoring to fully classify these areas.

Whilst we have not carried out a full investigation set out in guidance in the UKWIR document, the subject site does exhibit a degree of localised contamination and it is likely that barrier pipes will be required.

It is advised that Japanese Knotweed remedial specialists are contacted for advice and measures to deal with the significant stands suspected to be present around the site (in Zone 2) prior to construction and commencement any earthworks activities.

We have recommended further works which are detailed in Section 12.

2 Introduction

2.1 Objectives

2.1.1 This report describes a ground investigation carried out for a proposed housing development on land off Nunsfield Road, Fairfield, Buxton, Derbyshire, SK17 7HN.

2.1.2 The objective of the ground investigation was to establish ground conditions at the site, sufficient to identify possible foundation solutions for the development and provide parameters necessary for the design and construction of foundations and associated infrastructure.

2.1.3 The investigation included an evaluation of potential chemical and gaseous contamination of the site leading to the production of a risk assessment in relation to contamination.

2.1.4 The investigation has also been produced to support any future planning application for the site by satisfying National Planning Policy Framework (2019) section 178.

2.2 Status of this report

2.2.1 This report is final based on our current instructions. This report has been updated and as a consequence sections of this report have been amended as described in the index. Amendments to report text have been highlighted as follows: -

2.2.2 00 to 01 – updated following completion of the gas monitoring programme at the site. In addition, we have reported separately the investigations in relation to the proposed roundabout development, and reference should be made to our report R-STQ4642M-G02 for further details.

2.2.3 01 to 02 – updated following amendments to the development layout, including final levels. The update briefly comprises the exclusion of development within the area previously referred to as Zone 1, consisting of a former landfill. As a consequence, plot layouts and proposed reprofiling of the site have been amended to optimise more developable areas of the site.

2.2.4 02 to 03 – updated to reflect variation in number of dwellings to be constructed.

2.3 Client instructions and confidentiality

2.3.1 The investigation was carried out from January 2019 to March 2019 and originally reported in April 2019, acting on instructions received from the following parties; Barratt Homes Manchester, Derwent Lodge Estates Limited and Good REIT Ltd, whom shall jointly constitute 'the Client'. The report, as previously mentioned, was later updated in June 2019 (rev01) and August 2019 (rev02).

2.3.2 This report has been prepared for the sole benefit of our above named instructing client, but this report, and its contents, remains the property of Soiltechnics Limited until payment in full of our invoices in connection with production of this report.

2.3.3 Our original investigation proposals were outlined in our e-mail correspondence to Barratt Homes Manchester dated 14th November 2018. The investigation was subsequently amended following completion of a site reconnaissance and initial stages of intrusive investigations. The principal changes were: -

i) Due to large areas of suspected Japanese Knotweed identified in western areas of the site, mitigation measures were introduced to prevent the spread of likely rhizomes in near surface soils, as detailed in our email correspondence of 11th January 2019

ii) Due to encountering suspected ACMs in near surface soils present in the recorded landfill area, mitigation measures were introduced to satisfy HSE requirements where asbestos is suspected to be present onsite, as detailed in our email correspondence of 24th January 2019

iii) Based on the above, the duration of investigations was extended to ensure a sufficient number of exploratory points and site coverage was obtained, as detailed in our email correspondence of 24th January 2019

2.4 Site location and scheme proposals

2.4.1 The National Grid reference for the site is 406520, 374325. A plan showing the location of the site is presented on Drawing 01.

2.4.2 We understand the scheme will comprise the construction of a large number of dwellings, with associated gardens, infrastructure and access roads constructed to standards allowing adoption by the local highway authority.

2.4.3 Current development proposals are presented in Appendix O.

2.5 Report format and investigation standards

2.5.1 Sections 2 to 6 of this report describe the factual aspects of the investigation with Section 7 presenting an engineering assessment of the investigatory data. Section 8 provides a risk assessment of chemical contamination based on readily available historic records, inspection of the soils and laboratory testing. Section 9 provides a similar risk assessment in relation to gaseous contamination with Section 10, a risk assessment relating to construction materials likely to be in contact with the ground. Section 11 discusses issues relating to classification of waste soils for disposal and reuse.

2.5.2 Geotechnical aspects

2.5.2.1 Geotechnical investigations were carried out generally, and where practical following the recommendations of BS EN 1997:2 2007 '*Eurocode 7 – Geotechnical Design – Part 2: Ground Investigation and Testing*'. From a geotechnical viewpoint this is deemed to be a Ground Investigation Report (GIR) as set out in BS EN 1997:2. This report does not however does not constitute a Geotechnical Design Report as defined in section 2.8 of BS EN 1997-1:2004 *'Eurocode 7 – Geotechnical Design – Part 1: General Rules'* and in particular will exclude assessment of lifetime actions to buildings from geotechnical influences.

2.5.3 Geo-environmental aspects

2.5.3.1 The investigation process also followed the principles of BS10175:2011+A2:2017 *'Investigation of potentially Contaminated Sites – Code of Practice'*. In view of the client's requirement for rapid implementation of the investigation, the following elements, defined in BS10175, have been completed and incorporated in this report.

a) Phase I — Preliminary investigation (desk study and site reconnaissance)
b) Phase II — Exploratory and main (intrusive) investigations

2.5.3.2 The extent and result of the preliminary investigation (desk study) is reported in Section 3. Fieldwork combined the exploratory investigation and main investigation stages into one phase with the extent of these works described in Sections 4 and 6 of this report. Any supplementary investigations deemed necessary are identified in Section 12. Based on the results of the investigation, Section 8 will identify if any remediation is necessary with respect to chemical contamination, and a strategy for implementation. Similarly, Section 9 will identify if any remediation is necessary with respect to gaseous (landfill gas) contamination, and again a strategy for implementation.

2.5.3.3 This investigation has been carried out and reported based on our understanding of best practice. Improved practices, technology, new information and changes in legislation may necessitate an alteration to the report in whole or part after publication. Hence, should the development commence after expiry of one year from the publication date of this report then we would recommend the report be referred back to Soiltechnics for reassessment. Equally, if the nature of the development changes, Soiltechnics should be advised and a reassessment carried out if considered appropriate.

2.6 Report distribution

2.6.1 This report has been prepared to assist in the design and planning process of the development and normally will require distribution to the following parties, subject to Soiltechnics liabilities defined below, although this list may not be exhaustive:

Table summarising parties likely to require information contained in this report

Party	Reason
Client	For information / reference and cost planning
Developer / Contractor / project manager	To ensure procedures are implemented, programmed and costed
Planning department	Potentially to discharge planning conditions
Environment Agency	If ground controlled waters are affected and obtain approvals to any remediation strategies
Independent inspectors such as NHBC / Building Control	To ensure procedures are implemented and compliance with building regulations
Project design team	To progress the design
Principal Designer (PD)	To advise in construction risk identification and management under the Construction (design and management) regulations

Table 2.6

2.7 Soiltechnics liability

2.7.1 Soiltechnics disclaims any responsibility to our Client and others in respect of any matters outside the scope of this report. This report has been prepared with reasonable skill, care and diligence in accordance with the terms of our contract, taking account of the manpower, resources, investigations and testing devoted to it by agreement with our Client. This report is confidential to our Client and Soiltechnics accepts no responsibility of whatsoever nature to third parties to whom this report or any part thereof is made known. Any such party relies upon the report at their own risk.

3 Desk study information and site observations

3.1 General

3.1.1 As outlined in Section 2, the client has opted to exclude development of the former landfill area of the site, referred to as Zone 1. The factual content of this report section has not been amended to exclude reference to Zone 1, however, we have taken this into account within our interpretative assessments presented later in this report.

3.1.2 We have carried out a desk study which was limited to a review of readily available information including:

a) Review of published Ordnance Survey maps dating back to 1879 at various published scales

b) Inspection of geological maps produced by the British Geological Survey together with relevant geological memoirs

c) Consultation with Statutory Undertakers

d) Site reconnaissance

e) Other relevant published documents

3.1.3 We have obtained old Ordnance Survey maps using the Envirocheck database system. In addition to retrieval of historical and current Ordnance Survey data, Envirocheck provide information compiled from outside agencies including: -

- Ordnance Survey
- Environment Agency
- Scottish Environment Protection Agency
- The Coal Authority
- British Geological Survey
- Centre for Ecology and Hydrology
- Countryside Council for Wales
- Scottish Natural Heritage
- Natural England
- Health Protection Agency

3.1.4 The study did not extend to research of meteorological information or consultation with other interested parties such as English Heritage (ancient monuments), Ordnance Survey (survey control points), Planning Authorities or Archaeological Units.

3.1.5 A copy of records produced by Envirocheck is presented in Appendix M. Envirocheck produce a wealth of factual database information. Although we can provide a discussion on each of the database topics, this would produce a very lengthy document, but some of these discussions would not be relevant to the aims of this report. As a consequence, we have extracted some of the relevant topics and discussed them in this section of the report.

3.2 Description of the site

3.2.1 The site is positioned in the north-eastern part of Buxton, Derbyshire, approximately 700m from the town centre and located along the eastern and western flanks of Nuns Brook.

3.2.2 The site is approximately 17.8Ha in size and formed of a series of distinct parcels of land. A rectangular area of land in the north-western corner (termed Zone 1 later in the report) contained semi-mature to mature woodland and rough vegetation with undulating ground levels. Some localised steep slopes were present around the perimeter of this part of the site, which typically formed a 'plateaux' some 2-4m above surrounding ground levels. Nun Brook was culverted through this section of the site, running north to south adjacent to the eastern boundary of this area. A railway line formed the western site boundary. It should be noted that a large extent of this parcel of land was being redeveloped, associated with the railway, and was inaccessible and fenced off. Open land was present beyond the northern boundary.

3.2.3 Adjacently east of this area, (termed Zone 3 later in the report), and beyond the culverted channel of Nun Brook, was located grassed fields used for pasture. Stone walls and fences were present forming field boundaries, accommodating grazing animals locally. A residential property associated with Nunsfield Farm formed part of the site and located in the far eastern boundary of the fields. Surface levels in this area of the site fall significantly from east to west down to the channel of Nun Brook, by some 20-23m. An agricultural supply yard and buildings associated with Nunsfield Farm were present immediately adjacent to the east of this area of the site. Residential properties and a graveyard were located adjacent to the south, with further open land located adjacent to the north and part of Buxton & High Peak golf course located to the northeast.

3.2.4 To the south of the area of the site described in paragraph 3.2.2 above, was a further long, narrow rectangular parcel of land (termed Zone 2 later in the report). A ravine type feature was present between the parcels of land, some 5m deep in places. The southern slope of this area was partially retained by stone walls and the floor was partially stepped. To the south of this, the main body of this area was located on the eastern flanks of Nun Brook, the channel of which formed the eastern boundary. The area appears to have been subject to historic terracing, with a number of plateaus and embankment features present. Typically, surface levels generally fell from west to east by some 5m down towards the channel of the brook. The brook was also free flowing adjacent to this section of the site. This area was generally covered in woodland and parcels of dense vegetation, accessed by a network of north-south trending tracks surfaced in a mixture asphaltic concrete and gravel.

3.2.5 There were also a number of wooden shacks present in this area of the site, some burnt down with others in use, including for housing doves and chickens. A row of three prefabricated garages with evidence of a fourth, including a vehicular service pit, were present in the centre of this area. The south of this area was predominantly occupied by a grassed playing field which was generally flat, with children's play equipment present. To the south of the playing area were mature trees, where ground levels fall by some 3-4m to the south towards an area of prefabricated garages. Hogshaw Brook generally ran west to east and formed the southern boundary of the site, converging with Nun Brook to the southeast. Two footbridges and a small road bridge facilitated access to the garages and most of site. The railway line which forms the western boundary to Zone 1 also forms the western boundary to Zone 3, beyond which further residential properties are present. Residential properties were also located beyond the southern and eastern boundaries, also including allotments beyond the latter.

3.2.6 The far eastern parcel of land (termed Zone 4 later in the report), comprised of open land, covered in tended grass with localised semi mature and mature trees. Some parcels of this area formed part of the golf course as described in paragraph 3.2.3 above. Due to this, the northern area of Zone 4 was inaccessible at the time of our investigation. The A6 runs adjacently east of this area in a north to south direction, forming the site boundary. An access track leading to Nunsfield Farm forms the northern boundary to Zone 4, with Buxton & High Peak golf club located beyond, in addition to the northeast beyond the A6. A small number of residential properties, in addition to St Peters Church and associated graveyard form the western boundary to this area of the site.

3.2.7 A plan showing observed site features and location of exploratory points is presented on Drawing 02. Refer to Drawing 04 for a plan indicating the specific zones of the site as discussed above.

3.2.8 Photographic records of the site are presented in Appendix F.

3.3 Injurious and invasive weeds and asbestos

3.3.1 Injurious and invasive weeds

3.3.1.1 The following weeds are controlled under the Weeds Act 1959:

- Common Ragwort
- Spear Thistle
- Creeping or Field Thistle
- Broad leaved Dock
- Curled Dock

3.3.1.2 Whilst it is not an offence to have the above weeds growing on your land, you must:

- Stop them spreading to agricultural land, particularly grazing areas or land used for forage, like silage and hay
- Choose the most appropriate control method for the your site
- Not plant them in the wild

Should you allow the spread of these weeds to another parties land, Natural England could serve you with an Enforcement Notice. You can also be prosecuted if you allow animals to suffer by eating these weeds.

3.3.1.3 In addition to the above, you must not plant in the wild or cause certain invasive and non-native plants to grow in the wild as outlined in the Wildlife and Countryside act 1981. It is an offence under section 14(2) of the act to *'plant or otherwise cause to grow in the wild'* any plants listed in schedule 9, part II. This can include moving contaminated soil or plant cuttings. The offence carries a fine or custodial sentence of up to 2 years. The most commonly found invasive, non-native plants include:

- Japanese knotweed
- Giant hogweed
- Himalayan balsam
- Rhododendron ponticum
- New Zealand pigmyweed

You are not legally obliged to remove these plants or to control them. However, if you allow Japanese knotweed to spread to another parties land, you could be prosecuted for causing a private nuisance.

3.3.1.4 The presence of such weeds on site may have considerable effects on the cost / timescale in developing the site. Japanese knotweed can cause significant damage to buildings, roads and pavements following development, if untreated prior to development.

3.3.1.5 Our investigations exclude surveys to identify the presence of injurious and invasive weeds. It should be noted that we did observe areas of vegetation, generally to the south-western part of the site, which could be Japanese Knotweed. We recommend specialists in the identification and procedures to deal with injurious and invasive weeds are appointed prior to commencement of any works on site, or if appropriate purchase of the site, to confirm this.

3.3.2 Asbestos

3.3.2.1 Our investigations exclude surveys to specifically identify the presence or indeed absence of asbestos on site. It should be noted that asbestos containing material (ACM) and asbestos fibres were detected in samples of soil submitted for laboratory screening. The implications of the presence of asbestos in soils are discussed in Section 8 (contamination) and Section 11 (waste classification).

3.3.2.2 The presence of asbestos on site may have considerable effects on the cost / timescale in developing the site. There is good guidance in relation to Asbestos available on the Health and Safety Executive (HSE) web site.

3.4 History of the site

3.4.1 An attempt to trace the history of the site has been carried out by reviewing copies of old Ordnance Survey maps provided by Envirocheck. The recent history of the site based on published Ordnance Survey maps is summarised in the following table:

Summary description of site history from Ordnance Survey maps

Date	Onsite	Offsite
1879	Site recorded as open space and largely agricultural. Nuns Brook flows through the site and along south-eastern boundary similar to present day. Russia Mere (a pond) recorded in eastern part of site. Nuns Farm recorded in area of present day Nunsfield Farm.	Old lime kiln recorded 150m to the north. Quarry features located 200m to the east and northeast of the site. Graveyard and Church recorded adjacent to the south. Railway line recorded adjacent to western boundary. Brick Yard with pits recorded beyond railway line. Stream recorded along southern site boundary. Series of engine sheds, goods sheds, coal sheds, tanks, and slaughter houses recorded 15-200m to the south.
1882	No significant changes.	Quarries are located 400m to the northeast. Gas works recorded 300m to the south. Two quarries recorded approximately 700m to the west.
1898-99	Engine shed and railway sidings recorded in southwestern part of site with embankment, including turntable.	Carriage works 100m to the south. Laundry 200m to the southwest. Smithy recorded approximately 200m to the southeast.
1921-23	Allotment gardens with few small structures recorded in southern part of site. Further expansion of embankment adjacent to sidings. Nuns Farm now recorded as Nunsfield Farm.	Quarry recorded 200m to the northeast. Housing development recorded adjacent to south and south east boundary.
1938	No significant changes.	No significant changes.
1955	No significant changes.	No significant changes.
1966-67	Russia Mere no longer recorded. Refuse tip recorded in north-western part of site, with T shape structure. Nun Brook appears to be culverted through this part of the site. Further expansion of sidings in southwestern part of site, including coal hopper and tank. Allotment gardens to the south no longer recorded. Significant earthworks recorded in south-western/southern part of site similar to present day layout. Number of garages and sheds recorded in south-western and southern part of site.	Graveyard to south extended to adjacent to site. Earthwork around northwest corner of graveyard recorded within site boundaries. Quarries to east/northeast no longer recorded. Garage recorded 120m to the southeast of the site.
1973-74	All railway infrastructure to south/southwest of the site no longer recorded. Small number of garages present in central part of southern site area.	No significant changes.

Summary description of site history from Ordnance Survey maps		
Date	**Onsite**	**Offsite**
1975-77	No significant changes. Playing Field recorded in southern part of site, concurrent to present day layout.	Brake lining works and tyre depot noted in area of former carriage works. Much of railway adjacently to the west and south recorded as dismantled.
1989 - 2018	Expansion of Nunsfield Farm buildings. Refuse tip marked as workings (disused)	No significant changes.
Table 3.4.1		

3.4.2 In summary, the north-western part of site was open land until a refuse tip was recorded in 1967. The eastern part of the site was used as agricultural land with Russia Mere (a large pond) recorded between 1879 and 1967. The southern and south-western part of the site was used for various activities including a railway line with sidings including an engine shed (1898-1973), tanks and coal hopper (1967-1973), allotment gardens (1922 – 1967) and Playing Fields (1977-present day). In terms of adjacent and surrounding historical land, there were general railway and quarrying industries.

3.5 Geology and geohydrology of the area

3.5.1 Geology of the area

3.5.1.1 Envirocheck reproduce geological map extracts taken from the British Geological Survey (BGS) digital geological map of Great Britain at 1:50,000 scale (ref Appendix M). A summary of the recorded geological information for the site is presented in the following table:

Summary of Geology and likely aquifer containing strata					
Strata	**Bedrock or superficial**	**Approximate thickness**	**Typical soil type**	**Likely permeability**	**Aquifer designation**
Alluvium (confined to Nuns and Hogshaw Brooks)	Superficial	<5m	Clays, Silts, Sands, Gravels	Permeable	Secondary A Aquifer
Bowland Shale Formation (western and central parts of site)	Bedrock	>20m	Mudstone, Siltstone, and sandstone	Permeable	Secondary A Aquifer
Eyam Limestone Formation with Knoll Reefs (central and eastern parts of site)	Bedrock	<20m	Limestone	Permeable	Principal Aquifer
Bee Low Limestone Formation (eastern parts of site)	Bedrock	>70m	Limestone	Permeable	Principal Aquifer
Table 3.5.1					

3.5.1.2 A number of faults are recorded in close proximity of the site. The faults recorded adjacent to north-western corner and approximately 500m to the north are both located in Kinderscout Grit, Millstone Grit Group and Bowland Shale Formation. A further fault is recorded approximately 200m to the east within deposits of Bee Low Limestone Formation. Finally, a fault is recorded in between Bowland Shale Formation and Monsal Dale Limestone Formation to the south, which terminates at the southern boundary.

3.5.1.3 It should be noted that the following bedrock formations are recorded by BGS as present adjacent or in close proximity to the site. As such they may be present on site:-

- Kinderscout Grid – Sandstone
- Eyam Limestone Formation (Knoll-Reef) – Limestone
- Milestone Grit Group – Mudstone, Siltstone, Sandstone
- Monsal Dale Limestone Formation - Limestone

3.5.1.4 Superficial deposits are the youngest geological deposits formed during the Quaternary, which extends back about 2.6 million years. They rest on older deposits or rocks referred to as bedrock. Soil types and assessments of permeability are based on geological memoirs, in combination with our experience of investigations in these soil types.

3.5.1.5 Principal aquifers are defined as deposits exhibiting high permeability capable of high levels of groundwater storage. Such deposits are able to support water supply and river base flows on a strategic scale.

3.5.1.6 Secondary A aquifers are predominantly permeable layers capable of supporting water supplies at a local rather than strategic scale. In some cases, Secondary A aquifers can form an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

3.5.2 Water abstractions

3.5.2.1 4 active ground water and 5 active surface water abstraction points are located within 2000m of the site. The closest active groundwater abstraction point lies 672m to the southwest of the site with water abstracted for use as process water. The closest active surface water abstraction point lies 569m to the southwest of the site with water abstracted for general use.

3.5.2.2 The site is not located within a zone protecting a potable water supply abstracting from a principal aquifer (i.e. a source protection zone). However, a source protection zone 1 (SPZ 1) is present 380m to the south of the site.

3.5.3 Groundwater levels

3.5.3.1 We have reviewed the British Geological Survey (BGS) web site, and no borehole / trial pit records are available close to the subject site which may indicate the presence of groundwater in the local area.

3.5.4 Coal mining and brine extraction

3.5.4.1 The site is not recorded to be within an area affected by past or present coal mining, or minerals worked in association with coal or brine extraction (within the Cheshire Brine Compensation District).

3.5.5 Shallow mining and natural subsidence hazards

3.5.5.1 The British Geological Survey present hazard ratings for shallow mining and natural subsidence hazards. We can also confirm that we have obtained a mining and ground stability report from Envirocheck, which is presented in Appendix M. The site has the following ratings;

Table summarising mining and subsidence hazards

Hazard	Rating
Mining hazard in non-coal mining areas	Highly Unlikely
Potential for collapsible ground stability hazard	Very low
Potential for compressible ground stability hazard	**Moderate**
Potential for ground dissolution stability hazard	**Moderate to high**
Potential for landslide ground stability hazard	Low
Potential for running sand ground stability hazard	Low
Potential for shrinking or swelling clay ground stability hazard	Very low

Table 3.5.5

3.5.5.2 The moderate risk rating of compressible ground is associated with the presence of Alluvium in the area of Nun Brook and Hogshaw Brook, which can typically comprise soft organic clays/silts.

3.5.5.3 The moderate to high risk of ground dissolution is associated with limestones in the upper horizons of the Eyam Limestone Formation present within topographically lower parts of the site. Such areas typically lie adjacent to the channel of Nun Brook and limestones here are likely to be more susceptible to dissolution as groundwater and surface accumulates downslope in the lower portions of the site, which is also down dip of the limestone formations in the area (bedding planes dip to the west at ~22°). The high-risk areas are very localised and appear to be confined to the central parts of the site, immediately adjacent to the east of Nun Brook, however due to the mapping scale it is difficult to pin point the actual locations.

3.5.5.4 Envirocheck also records the presence of a natural sink hole and solution pipe 596m to the southeast of the site, present within limestone deposits. The risks associated with dissolution are discussed further in Section 7.

3.5.6 Borehole records

3.5.6.1 The British Geological Survey (BGS) retain records of boreholes formed from ground investigations carried out on a nationwide basis. The location of boreholes with records held by the BGS is recorded on the borehole map contained in Appendix N. We do not normally obtain copies of these records but can do on further instructions. There is normally a charge made by the BGS for retrieving and copying these records.

3.6 Landfill and infilled ground

3.6.1 Envirocheck reports one landfill site in the north-western portion of site, known as Hogshaw refuse tip. Records indicate the site was licenced for receipt of domestic, inert, industrial and commercial wastes, and licence has now lapsed. Furthermore, the Local Authority planning portal of High Peak Borough Council, also records a refuse tip in the area of the existing recreation ground to the southwest of the site (Zone 2).

3.6.2 In addition, we have reviewed old Ordnance Survey maps and there is obvious evidence of quarrying in the area, the closest of which is 200m to the east of site. It is not clear from mapping if the quarries have been restored.

3.6.3 12 BGS mineral sites are recorded within 1000m from site. The closest is located 219m to the northwest, extracting common clay and shale. All mineral sites were opencast type, used to extract common clay, shale or limestone. Extraction at all 12 sites is recorded to have ceased.

3.6.4 A number of infilled land and water bodies are also recorded on site and within 1000m of the site. Table below summarises Envirocheck records.

Summary of Infilled Ground

Landfill name	Type	Location	Use	Date of mapping
Potentially infilled land	Non water	136m NW	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	227m NE	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	332m NE	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	426m E	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	439m NE	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	440m E	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	571m E	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	663m E	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	791m E	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	877m NW	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Non water	976m NE	Unknown filled ground (pit, quarry)	1977
Potentially infilled land	Water	On site	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	33m SW	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	52m SW	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	115m SW	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	184m E	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	244m E	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	328m SW	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	376m E	Unknown filled ground (pond, marsh, river, stream, dock)	1955
Potentially infilled land	Water	736m NE	Unknown filled ground (pond, marsh, river, stream, dock)	1955

Table 3.6.4

3.6.2 The feature recorded onsite is associated with the backfilling of Russia Mere, recorded on historical mapping between 1879 and 1967. The 3 areas adjacent to the southwest of the site appear to be related to localised infilling of the channel of Hogshaw Brook.

3.7 Radon

3.7.1 Envirocheck use the British Geological Survey database to review reported radon levels in the area in which the site is located to establish recommended radon protection levels for new dwellings. The database records the site as being located where full protection is recommended.

3.7.2 The Building Research Establishment publication applies to all new buildings, conversions and refurbishments whether they are for domestic or non-domestic use.

3.7.3 It is noteworthy that the BRE and BGS / HPA information is based on statistical analysis of measurements made in dwellings in combination with geological units, which are known to emit radon. Consequently, there is a risk for actual radon levels at the site to exceed the levels assessed by the BGS / HPA / BRE. Currently, the only true method of checking actual radon levels is by measurement within a building on the site over a period of several months. It should be noted that it is not currently a requirement of the Building Regulations to test new buildings for radon, however the BRE recommends testing on completion or occupation of all new buildings (domestic and non-domestic), extensions and conversions. Should you wish to undertake radon monitoring following completion of the development, we can provide proposals.

3.8 Flood risk

3.8.1 The site is not located within a fluvial or tidal flood plain, with the exception of the far southern part of the site on the southern and south-eastern site boundaries, associated with Hogshaw and Nun Brooks. Areas in the immediate vicinity of Nun Brook are recorded at high risk of surface water flooding. Furthermore, the eastern part of the site has limited potential for groundwater flooding to occur, however localised areas along the course of Nun Brook have potential for groundwater flooding to occur at surface.

3.8.2 It should be noted that this information does not constitute a site specific Flood Risk Assessment (FRA), and a full FRA may be required for the development to support a planning application or satisfy planning conditions.

3.9 Environmental sensitivity

3.9.1 Sensitive land use

3.9.1.1 Based on information provided by Envirocheck, two sensitive land use areas are recorded within 1000m from site. An environmentally sensitive area named South West Peak is recorded 17m to the northwest, however, is termed ‘decommissioned’. An area of ancient woodland called Corbar Woods is also recorded 763m to the west of the site.

3.9.2 Pollution incidents

3.9.2.1 The Envirocheck recorded 15 pollution incidents to controlled waters situated within 1000m of the subject site. 11 of these are recorded as Category 3 – Minor Incidents, with the rest termed Category 2 – Significant Incidents. The nearest incident is recorded 189m to the south of site, associated with release of oils/diesel into Hogshaw Brook, dated in February 1998. The closest significant incident is recorded 316m to the south, associated with release of unknown organic wastes into Hogshaw Brook, dated April 1997.

3.9.3 Industrial land use

3.9.3.1 24 trade directory entries are recorded within 500m of the subject site. 9 of these are recorded as active, the closest of which is recorded 13m to the northeast, classified as Garage Services at Nunsfield Farm (Buxton 4x4). The closest inactive entry is located 5m to the northeast, associated with an Agricultural Merchants at Nunsfield Farm.

3.10 Enquiries with statutory undertakers

3.10.1 We have contacted the following Statutory Undertakers (SUs) to obtain copies of their records in order to avoid damaging their apparatus during our fieldwork activities: -

a) BT Openreach Ltd
b) Cadent Gas
c) Severn Trent Water
d) Electricity Northwest

3.10.2 Furthermore, we can confirm that the client has also provided copies of further following Statutory Undertakers (SUs) plans, listed below: -

a) Western Power Distribution
b) ESP Utilities Group
c) Virgin Media
d) C.A. Telecom
e) Instalcom
f) Plancast
g) SKY
h) SOTA

3.10.3 Copies of responses received prior to publication of this report are presented in Appendix L. These records have been obtained solely for the purposes described above. Some of these records have been obtained from the Internet and from our database without contacting the statutory undertaker direct. Occasionally, SU information is recorded on drawings larger than A3, and thus cannot be easily presented in this report. In such cases we will copy the correspondence but not incorporate the drawing in this report, and maintain the records on our office file.

3.10.4 We have visited the Linesearch web site (www.linesearchbeforeudig.co.uk) which provides a report on national grid networks (National Gas and Electricity Transmission Networks). Again a copy of their report is presented in Appendix L.

3.10.5 In addition we have received records of Nestlé Waters UK Ltd pipe which traverses across the site. A copy of their records is presented in Appendix L. The route of the pipe is also presented on Drawing 02.

3.10.6 Normally Statutory Undertakers drawings record the approximate location of their services. We recommend further on site investigations be undertaken to confirm the position of the apparatus and thus establish the effect on the proposed development and the necessity or otherwise for the permanent or temporary diversion of the service to allow the construction of the development to safely and successfully proceed.

3.10.7 It should be noted that statutory undertakers' records normally exclude private services.

3.11 Enquiries with local authority building control and environmental health officers

3.11.1 We have contacted Local Authority Building Control and Environmental Health Officers at High Peak Borough Council regarding the site. We have not received a response to date. If any information of notable relevance is received following issue of this report we will update accordingly.

4 Fieldwork

4.1 General

4.1.1 Fieldwork comprised the following activities, undertaken between 21st January and 8th February 2019: -

- Excavation of twenty exploratory trial pits (TP01-TP20)
- Excavation of twenty-eight exploratory boreholes formed using driven tube sampling equipment (DTS01-DTS13 and DTS15 to DTS29). DTS14 was not undertaken due to time constraints.
- Infiltration testing undertaken in 3 borehole locations (DTS06, DTS13 and DTS19)

4.1.2 A plan of the site showing existing site features and position of exploratory points is presented on Drawings 02. The position of exploratory points relative to site development preliminary proposals is presented on Drawing 03. The position of exploratory points shown on these plans is approximate only.

4.1.3 The extent of fieldwork activities and position of exploratory points were determined by Soiltechnics.

4.1.4 Exploratory points were positioned to avoid known locations of underground services, to avoid possible location of proposed foundations but were also positioned to provide a reasonable coverage of the site. Prior to commencement of exploratory excavations an electronic cable locating tool was used to scan the area of the excavation. If we received a response to this equipment then the excavation would be relocated.

4.1.5 All soils exposed in excavations were described in accordance with BS EN ISO 14688 *'Identification and Classification of soil'* and BS EN ISO 14689 *'Identification and classification of rock'.*

4.2 Site restrictions

4.2.1 At the time of our investigation the site was open to the public and generally accessible to mechanical excavators and the driven tube sampler borehole rig. The only exception were areas of the site with excessively steep slopes, the western area of the site (Zone 1) adjacent to the railway, which was fenced off and under construction, and the northern area of Zone 4 which formed part of the adjacent golf course. Locations were also positioned remote from potential service locations.

4.2.2 It should also be noted that in large areas of Zones 1 and 2, suspected Japanese Knotweed was present. Precautions were taken to prevent the spread of associated rhizomes by washing down equipment after each excavation and prior to moving to the next. Furthermore, suspected ACMs were encountered in soils in the landfill area of Zone 1. As such excavations were avoided where possible. However, where excavations were necessary, precautions were taken to prevent the release of possible asbestos fibres into the air, by dampening down and providing suitable welfare facilities in case of exposure.

4.3 Exploratory trial pits

4.3.1 Trial pits TP01 to TP20 were excavated to a maximum depth of 4.3m using a 360° tracked or rubber tyred excavator. The excavations were backfilled with excavated material compacted using the back of the excavator bucket. Whilst we attempted to reinstate the excavation to its original condition the soils could not be fully compacted into the trial pit and thus the soils were left proud of the ground surrounding the pit to allow for short-term settlement of the backfill. A Geotechnical Engineer supervised the excavations.

4.3.2 Sampling and logging was carried out as trial pit excavations proceeded but were not entered at depths exceeding 1.2m, or where trial pit sides were deemed unstable. The density of granular soils encountered in excavations was gauged by the ease of excavation.

4.3.3 Soil samples for subsequent laboratory determination of concentration of chemical contaminants were taken from the sides of trial pits using clean stainless-steel equipment and stored in new plastic containers, which were labelled and sealed. Samples from below access depth into trial pits were taken as a sub sample from soil contained in the excavator bucket, discarding any soil, which may have been in contact with the bucket. If as a consequence of visual or olfactory evidence, a sample was suspected to be contaminated by organic material, the sample was stored in an amber glass jar with a PTFE sealing washer.

4.3.4 Soil samples for subsequent laboratory ‘classification’ testing were taken from the side of trial pits or from bulk samples taken from the excavator bucket. The sample was immediately placed in a plastic bag and subsequently sealed and labelled. Samples for determination of water content were placed in sealable tubs and appropriately labelled. Soil samples were obtained to meet Category A and quality class 3 to 5 as described in BS EN I997-2:2007 (table 3.1) sufficient for laboratory testing being considered. Sample sizes were also appropriate for the laboratory test being considered (refer BS EN I997-2:2007 Annex L).

4.3.5 A pocket penetrometer was used in the cohesive (fine grained) soils encountered. This tool is deemed to measure the apparent ultimate bearing capacity of the soil under test. The pocket penetrometer is calibrated in kg/cm^2. The reading can be approximately converted to equivalent undrained shear strength by multiplying the results by a factor of 50. Tests were carried out in the sides of trial pits when access can be safety achieved otherwise testing was carried out on excavated intact clods. Details of pocket penetrometer determinations are tabulated in Appendix C2. An average of measurements taken at a specific depth are recorded on trial pit records. The pocket penetrometer is not covered by British Standards.

4.3.6 A summary of pocket penetrometer results obtained from the cohesive soils encountered in exploratory excavations are presented in graphical format on Drawings 06a to 06f.

4.3.7 Trial pit records are presented in Appendix D.

4.4 Boreholes formed using driven tube sampling techniques

4.4.1 Boreholes DTS01 to DTS29 were formed using driven tube sampling equipment to a maximum depth of 5.0m. Driven tube sampling comprises driving 1m long steel sample tubes which are screw coupled together or coupled to extension rods and fitted with a screw on cutting edge. The sample tubes are of various diameters, generally commencing with 100mm and reducing, with depth, to 50mm and include a disposable plastic liner which is changed between sampling locations in order to limit the risk of cross contamination. On completion of excavation the liner containing the sample is cut open and the soil sample logged by a geo-environmental engineer. The sample tubes are considered thick walled with reference to BS EN ISO 22475-1:2006 clause 3.3.11.

4.4.2 Samples for determination concentration of chemical contaminants are taken from samples obtained in the disposable tubes as sub-samples using stainless steel sampling equipment.

4.4.3 Soil samples for subsequent laboratory ‘classification’ testing were taken from samples obtained in the disposable tubes. The sample was placed in a plastic bag and subsequently sealed and labelled. Samples for determination of water content were placed in sealable tubs and appropriately labelled. These samples were obtained with a view to achieve category B sampling methods to meet quality class 3 (for fine grained soils only) as described in BS EN ISO 22475-1: 2006 (table 3). Sample sizes were appropriate for the laboratory test being considered.

4.4.4 Standard Penetration Testing (SPT) was carried out at regular frequencies in the borehole. The test was carried out in accordance with BS EN ISO 22476-3:2005. Key details of the test, as required by BS EN ISO 22476-3 are recorded in Appendix C1. SPT's were carried out using a solid 60° cone in granular material, this test is reported as SPT(C) or using an open sampler in cohesive material, reported as SPT(S). Summary of standard penetration testing is recorded on borehole logs.

4.4.5 A graphical summary of standard penetration test results is presented on Drawings 07a-07f.

4.4.6 Again, a pocket penetrometer was used in cohesive soils. Details of pocket penetrometer determinations are tabulated in Appendix C2. An average of measurements taken at a specific depth are recorded on borehole records. The pocket penetrometer is not covered by British Standards.

4.4.7 A graphical summary of pocket penetrometer measurements is presented on Drawings 06a to 06f.

4.4.8 Combined gas and groundwater monitoring standpipes were installed in boreholes DTS04, DTS06, DTS13, DTS19, DTS24. The standpipes were installed following the recommendations of BS EN ISO 22475-1:2006 '*Geotechnical Investigation and Testing – Sampling methods and groundwater measurements – Part 1: Technical Principles for execution*' (figure 6) and BS8576:2013 *'Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'* (figure 7). Details of the standpipe installation are recorded on Drawing 08.

4.4.9 Water levels in the standpipes have been measured during return visits to the site. The water level was measured using a measuring tape calibrated in 1mm intervals with an electronic end piece, which emits an alarm sound in contact with water. Water levels are measured from ground levels at the borehole position. Records of water levels are presented on Appendix K.

4.4.10 A description of measurement of landfill type gases in gas monitoring standpipes is provided in subsequent report paragraphs below.

4.4.11 Indicative soil infiltration testing was carried out in boreholes DTS06 and DTS13. The infiltration testing was carried out generally in accordance with the procedure described in Building Research Establishment (BRE) DG 365 (2016) "*Soakaway Design*". Records of test results and calculations to determine a soil infiltration rate are presented in Appendix C3. It should be noted that testing has not been carried out strictly in accordance with the BRE publication, as this does not specifically provide for calculating an infiltration rate in a borehole. We have adapted the BRE method and calculations in order to provide an indicative infiltration rate.

4.4.12 Permeability testing was carried out in borehole DTS19 following the procedures described in BS EN ISO 22282-2:2012 *'Water permeability tests in a borehole using open systems'*. Records of the test results and calculations to determine the coefficient of permeability (k) are presented in Appendix C3.

4.4.13 Records of boreholes formed using driven tube sampling techniques are presented in Appendix E.

4.5 Measurement of landfill type gases in gas monitoring standpipes

4.5.1 The concentrations of landfill type gases collected within gas monitoring standpipes installed in boreholes DTS04, DTS06, DTS13, DTS19, DTS24 was measured using a portable infra-red gas analyser (model GA5000, manufactured by Geotechnical Instruments). Initially the gas analyser was connected to the gas valve on the top of the standpipe to allow the flow rate to be measured. Essentially this is a measurement of gas pressure produced in the standpipe, which is compared with atmospheric pressure at the time of measurement to produce an equivalent gas 'flow' in l/hr. The equipment used is capable of measuring to an accuracy of 0.1l/hr; below this the gas analyser records zero flow. Following BS8485:2015 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings* (clause 6.3.4), we assume flows of 0.1l/hr when the gas analyser reads zero, thus producing a pessimistic gas flow rate in our assessment of ground gases.

4.5.2 Following measurement of 'flow' the gas analyser pumps gases contained in the standpipe through the analyser. Initial readings of gas concentrations are noted manually, followed by subsequent recordings at regular time periods until 'steady state' concentrations are achieved. The analyser records 'peak' and 'steady' concentrations of the following gases:

- Methane (CH_4)
- Carbon dioxide (CO_2)
- Oxygen (O_2)

4.5.3 The ambient atmospheric temperature and barometric pressure was also recorded at the site. To determine if the atmospheric pressure is rising or falling we interrogate the internet on a daily basis.

4.5.4 Methane in concentrations of between 5 to 15% in air is potentially explosive. The 5% methane concentration in air is defined as the Lower Explosive Limited (LEL). The gas analyser measures a percentage of the LEL. For example, 10% LEL equates to 10% of 5%, i.e. 0.5% methane concentration in air.

4.5.5 Records of gas monitoring data are presented in Appendix K.

4.6 Sampling strategies

4.6.1 Geotechnical

4.6.1.1 In general we adopted a judgemental sampling strategy in relation to geotechnical aspects of the investigation. The location and frequency of sampling was carried out in consideration of the following:

i) Topography
ii) Geology (including Made Ground)

iii) Nature of development proposals

4.6.2 Environmental

4.6.2.1 Details of sampling with respect to contamination issues are described in Section 8.

4.6.3 Sample retention

4.6.3.1 Samples are stored for a period of one month following issue of this report, unless otherwise requested.

5 Laboratory testing

5.1 Classification

5.1.1 Laboratory testing was carried out on samples retrieved from site. The method of testing is recorded on the laboratory test certificate. The following table summarises the classification testing scheduled;

Table summarising classification testing

Exploratory point	Depth (m)	Soil type	Testing scheduled (determination of)
TP01	0.8	Clay	Atterberg Limits, moisture content
TP06	1.2	Clay	
TP07	3.5	Clay	
DTS12	1.2	Clay	
DTS15	0.8	Clay	
DTS17	0.8	Clay	
DTS18	1.8	Clay	
DTS19	3.5	Clay	
DTS23	2.5	Clay	
DTS24	3.5	Clay	
TP01	0.5	Gravel	Particle Size Distribution with hydrometer, moisture content
TP04	0.5	Gravel	
TP08	2.6	Sand	
TP09	2.5	Gravel	
TP11	1.2	Gravel	
TP12	1.2	Gravel	
TP15	1.2	Sand	
TP19	1.2	Sand	
TP20	2.5	Clay	
TP10	3.0	Gravel	Particle Size Distribution, moisture content

Table 5.1.1

5.1.2 Laboratory test certificates are presented in Appendix G.

5.2 Chemical testing

5.2.1 Chemical testing was carried out based on ground conditions and with reference to the contamination Initial Conceptual Model as presented in Section 8. The test methods are recorded on the chemical test certificates. The following table summarises the chemical testing scheduled;

Table summarising chemical testing

Exploratory point	Depth (m)	Medium/soil type	Testing scheduled (Refer to Appendix B for details)
TP01	0.3	Gravel	Suite 1
TP02	0.3	Sand	
TP03	0.2	Topsoil	
TP04	0.2	Topsoil	

Table summarising chemical testing			
Exploratory point	Depth (m)	Medium/soil type	Testing scheduled (Refer to Appendix B for details)
TP05	0.8	Made Ground - Sand	
TP06	0.3	Topsoil	
TP10	0.8	Made Ground - Sand	
TP11	0.3	Topsoil	
DTS01	0.5	Made Ground - Clay	
DTS01	0.8	Made Ground - Clay	
DTS02	0.3	Topsoil	
DTS03	0.3	Topsoil	
DTS04	0.5	Made Ground - Clay	
DTS06	0.3	Topsoil	
DTS07	0.3	Topsoil	
DTS09	0.3	Topsoil	
DTS12	0.3	Topsoil	
DTS15	0.3	Topsoil	
DTS18	0.3	Topsoil	
DTS20	0.5	Made Ground - Sand	
DTS20	0.8	Made Ground - Sand	
DTS23	0.8	Made Ground - Sand	
DTS28	0.8	Clay	
TP05	0.8	Made Ground - Sand	Asbestos Screening
TP07	0.5	Made Ground - Gravel	
TP09	0.5	Made Ground - Gravel	
TP18	0.8	Made Ground - Sand	
TP18	1.2	Made Ground - Sand	
TP18	1.4	Made Ground - Sand	
TP18	1.6	Made Ground - Sand	
DTS13	0.8	Made Ground - Sand	
DTS16	0.8	Made Gravel - Gravel	
DTS20	0.8	Made Ground – Sand	
DTS21	0.5	Made Ground - Sand	
DTS22	1.2	Made Ground - Sand	
DTS26	0.8	Clay	
DTS28	0.8	Clay	
DTS29	1.2	Made Ground - Sand	
TP03	0.5	Gravel	Suite 8
TP16	0.5	Made Ground - Gravel	
TP18	0.5	Made Ground - Sand	
TP20	0.5	Made Ground - Sand	
DTS02	0.5	Sand	
DTS07	0.8	Clay	
DTS19	0.5	Made Ground - Sand	
DTS19	1.2	Gravel	
DTS21	1.8	Made Ground - Clay	
DTS22	1.8	Clay	
TP05	2.5	Made Ground - Sand	Suite 2 - Leachate
TP07	0.8	Made Ground - Gravel	
TP05	1.2	Made Ground – Sand	Suite 17
TP05	1.8	Made Ground – Sand	
TP08	0.8	Made Ground – Sand	
TP08	1.2	Made Ground – Sand	
TP09	0.8	Clay	
TP20	1.2	Made Ground – Clay	
DTS04	0.8	Made Ground – Gravel	
DTS09	0.5	Clay	
DTS16	0.8	Made Ground - Gravel	
DTS20	1.2	Made Ground - Sand	
DTS25	0.5	Made Ground - Sand	

Table summarising chemical testing

Exploratory point	Depth (m)	Medium/soil type	Testing scheduled (Refer to Appendix B for details)
Nuns Brook Upstream	Surface	Water	
Nuns Brook Downstream	Surface	Water	Suite 17 - Water
DTS19	3.2	Water	

Table 5.2.1

5.2.2 Laboratory testing was carried out by an independent specialist testing house, which operates a quality assurance scheme. Laboratory test certificates for chemical testing are presented in Appendix H.

6 Ground conditions encountered

6.1 Soils / Rocks

6.1.1 The exploratory excavations encountered the following geological formations across the site: -

- Topsoil
- Made Ground
- Weathered Bee Low Limestone Formation
- Weathered Eyam Limestone Formation
- Weathered Bowland Shale Formation

6.1.2 In addition, locally across the main development area, reworked naturally deposited soils were suspected to be present (TP09, DTS18, DTS22 and DTS26).

6.1.2 For clarity we have referred to the composition of soils within each of the Zones as described in Section 3 and presented on Drawing 04.

6.1.3 Made Ground

6.1.3.1 Within Zone 1 Made Ground was typically encountered as medium dense, dark brown or dark grey, very gravelly SAND or very sandy GRAVEL. Gravel consisted of coarse angular bricks, concrete, glass, plastic, metal wire, vehicle parts, shoes, paper, timber ceramic tiles, roof tiles and slag, with such deposits encountered to depths beyond 5m. The material was consistent with landfilling as recorded by Envirocheck, which appeared to be of 1950-80s origin.

6.1.3.2 Within Zone 2, the Made Ground was consistent with that encountered in Zone 1 (although not physically recorded as a landfill site), but included increased volumes of slag, brick, coal and glass, and was typically much ashier in composition. It is thought that the deposition of the waste here possibly dates from around the late 1800s to early 1900s based on evidence on newspaper clippings encountered in excavations. Made Ground in Zone 2 typically ranged to between depths of 3.0m to >5m to the east and south, with deposits ranging between 0.8m to 1.5m to the northwest of the area. This is likely to be a result of the terracing that this area of the site has been subject to historically.

6.1.3.3 Made Ground in Zone 4 to the east of the site was similar in composition to that encountered in Zone 2, particularly in the location of the former mere (DTS13 and DTS18). No significant Made Ground was encountered in Zone 3.

6.1.4 Weathered Bee Low Limestone Formation

6.1.4.1 Weathered Bee Low Limestone Formation was typically encountered as medium dense orangish brown slightly silty fine SAND or stiff high strength orangish brown sandy CLAY. In the majority of excavations, such deposits extended beyond depths of 5m, however, locally refused at depths of between 1.0m to 3.3m. Refusal is likely to be attributed to encountering more competent deposits of bedrock. Such deposits were only encountered in the eastern part of the site within Zone 4.

6.1.4.2 It should be noted that deposits encountered in borehole DTS18 are suspected to have been reworked, based on their density/strength and depositional characteristics.

6.1.5 Weathered Eyam Limestone Formation

6.1.5.1 Weathered Eyam Limestone Formation was encountered in Zone 3 and the eastern most parts of Zone 2 only, locally below Made Ground deposits. Such deposits were typically encountered as medium dense brown SAND or very sandy GRAVEL of sandstone and shale in the northern parts of Zone 3, and across the rest of the areas as firm to stiff low to medium strength sandy gravelly CLAY. Gravel consisted of fine to coarse angular mudstone and limestone. Rare limestone cobbles / boulders were encountered locally. Generally, all excavations refused between depths of 0.88m to 3.9m below surface levels. Again. refusal is likely to be attributed to encountering more competent deposits of bedrock.

6.1.6 Bowland Shale Formation

6.1.6.1 Bowland Shale Formation was initially encountered as a weathered material below Made Ground, present in Zone 2 and western parts of Zone 3. Deposits typically comprised of firm to stiff, low to medium strength, light brown mottled dark brown, sandy in places, CLAY. Also, such deposits were encountered as a medium dense orangish brown SAND or loose to medium dense grey GRAVEL of angular limestone, sandstone or shale.

6.1.6.2 Locally, in the areas of TP09, DTS22 and DTS26, deposits of weathered Bowland Shale Formation were suspected to have been reworked, based on their density/strength and depositional characteristics.

6.1.6.3 In one location (DTS10), Bowland Shale was encountered as bedrock comprised of very weak dark grey thickly laminated mudstone. In the majority of excavations, such deposits extended beyond depths of 4-5m, however, locally refused at depths of between 3.3m and 3.45. Excluding DTS10, refusal was likely to be attributed to encountering more competent deposits of bedrock.

6.1.7 Summary

6.1.7.1 The following table summarises the geology encountered.

Table summarising soil types

Strata	Depth to top (m)	Depth to bottom (m)	Thickness (m)	Summary description
Topsoil (Zone 3, 4)	0.0	0.15 – 0.5 (0.3)	0.15 – 0.5 (0.3)	Dark brown SAND and CLAY.
Made Ground (Zone 1)	0.0	>5.45	Strata not penetrated (>5.45)	Medium dense, dark brown or dark grey, very gravelly SAND or very sandy GRAVEL. Gravel consists of coarse angular bricks, concrete, glass, plastic, metal wire, car parts, shoes, paper, timber, ceramic tiles, roof tiles, slag.
Made Ground (Zones 2 & 4)	0.0	0.3 ->5.45 (1.65)	0.3 – >5.45 (1.65)	Very Loose dark brown or dark grey, very gravelly slightly clayey SAND, or very sandy gravel GRAVEL. Gravel consists of coarse angular ash, slag, coal, shale, bricks, concrete with minor, glass, plastic, metal wire, car parts, shoes, paper, timber, ceramic tiles and roof tiles. Also includes suspected reworked natural soils.
Weathered Bee Low Limestone Formation (Zone 4)	0.3 – 1.6 (1.0)	Strata not penetrated	Strata not penetrated (>5.45)	Medium dense orangish brown gravelly slightly silty fine SAND or stiff high strength orangish brown sandy CLAY.
Weathered Eyam Limestone Formation (Zone 3)	0.2 – 1.5 (0.4)	Strata not penetrated	Strata not penetrated (>5.45)	Firm low strength light brown mottled dark brown CLAY or medium dense orangish brown SAND or medium dense grey GRAVEL of coarse angular limestone or shale.
Weathered Bowland Shale Formation (Zone 2, 3)	0.3 – 3.0 (1.43)	Strata not penetrated	Strata not penetrated (>5.45)	Medium dense brown very sandy GRAVEL or Firm, low strength sandy gravelly CLAY. Gravel consisted of fine to coarse angular mudstone and limestone.
Bowland Shale Formation bedrock (Zone 3)	2.8 (DTS10 only)	Strata not penetrated	Strata not penetrated (>3.45)	Very weak dark grey thickly laminated mudstone

Table 6.1.7

Figures in brackets are average values

6.1.7.2 With the exception of Made Ground, the investigation generally confirmed published geological records.

6.2 Geotechnical parameters

6.2.1 The following table summarises test data in the weathered Bowland Shale Formation (in Zone 2 and western parts of Zone 3).

Table summarising soil testing and derived geotechnical parameters					
Geotechnical parameter	**Method**	**Value range**	**Characteristic value**	**Comments**	**Notes**
Weight density (above water table)	Soil descriptions	15-19 kN/m³	15kN/m³	Derived from BS 8004 figure 1. Most suitable value to be used in structural design.	
Weight density (below water table)	Soil descriptions	14-19 kN/m³	14kN/m³	Derived from BS 8004 figure 2. Most suitable value to be used in structural design.	
Plasticity index	Laboratory testing	18-45	31	Report average as representative of the soil as a whole.	1
Water content (%)	Laboratory testing	16 – 62	N/A		1
Undrained Shear strength (kN/m²)	Insitu testing	10-150 kN/m²	50kN/m²	Typical value adopted.	2
Table 6.1.2.1					

1. Laboratory testing presented in Appendix G.
2. Presented on Drawings 06a-06f

6.2.2 The following table summarises test data in the weathered Eyam Limestone Formation (in Zone 3).

Table summarising soil testing and derived geotechnical parameters					
Geotechnical parameter	**Method**	**Value range**	**Characteristic value**	**Comments**	**Notes**
Weight density (above water table)	Soil descriptions	15-19 kN/m³	15kN/m³	Derived from BS 8004 figure 1. Most suitable value to be used in structural design.	
Weight density (below water table)	Soil descriptions	14-19 kN/m³	14kN/m³	Derived from BS 8004 figure 2. Most suitable value to be used in structural design.	
Plasticity index	Laboratory testing	17 – 37	25	Report most common as representative of the soil as a whole.	1
Water content (%)	Laboratory testing	7.3 - 65	N/A		1
Undrained Shear strength (kN/m²)	Insitu testing	20-100 kN/m²	50kN/m²	Typical value adopted.	2
Table 6.2.2					

1. Laboratory testing presented in Appendix G.
2. Presented on Drawings 06a-06f

6.2.3 The following table summarises test data in the weathered Bee Low Limestone Formation (in Zone 4).

Table summarising soil testing and derived geotechnical parameters					
Geotechnical parameter	**Method**	**Value range**	**Characteristic value**	**Comments**	**Notes**
Weight density (above water table)	Soil descriptions	15-19 kN/m^3	15kN/m^3	Derived from BS 8004 figure 1. Most suitable value to be used in structural design.	
Weight density (below water table)	Soil descriptions	14-19 kN/m^3	14kN/m^3	Derived from BS 8004 figure 2. Most suitable value to be used in structural design.	
Plasticity index	Laboratory testing	23	23	Report value tested	1
Water content (%)	Laboratory testing	32-44	N/A		1
Undrained Shear strength (kN/m^2)	Insitu testing	0-117 kN/m^2	50kN/m^2	Typical value adopted.	2

Table 6.2.3

1. Laboratory testing presented in Appendix G.
2. Presented on Drawings 06a-06f

6.3 Topsoil

6.3.1 As a practice we have adopted the following policy for description of topsoil. If surface soils exhibit a visually significant organic content and darker colour than the soils it overlies (which are considered to be naturally deposited) then we will describe the soil as topsoil. In some cases, it is difficult to visually distinguish the interface between topsoil and subsoils below, which may also exhibit an organic content, and in such cases we will adopt an estimate of the interface but may also use the terms 'grading into' with some defining depths.

6.3.2 If 'topsoil' deposits include materials such as ash, brick and other man-made materials, or the topsoil overlies Made Ground deposits we will term the material 'Made Ground', even though it may still be able to support vegetable growth, and potentially reused as topsoil.

6.3.3 Topsoil can be classified following a number of test procedures as described in BS3882:2015 *'Specification for Topsoil'* to allow its uses to be determined. We do not carry out such testing unless specifically instructed to do so.

6.4 Groundwater

6.4.1 Groundwater inflows were observed in many of the exploratory excavations. A summary of our observations is tabulated below:

Table summarising groundwater observations			
Exploratory point	**Date of observation**	**Depth (m) bgl**	**Observations**
DTS02	08/02/2019	1.3	Groundwater encountered at 1.9m, filling borehole to 1.3m in 10 minutes.
DTS03	08/02/2019	2.0	Groundwater encountered at 2.3m, filling borehole to 2.0m in 10 minutes.
DTS04	06/02/2019	3.0	Groundwater level remain constant.
DTS05	06/02/2019	3.0	Groundwater level remain constant.
DTS10	06/02/2019	1.0	Groundwater level remain constant.
DTS29	29/01/2019	3.0	Groundwater level remain constant.
TP09	22/01/2019	1.3	Groundwater seepages encountered at 1.3m and 2.0m. Not sufficient to fill the pit.
TP12	21/01/2019	4.2	Seepage observed at 4.3m, filling trial pit to 4.2m in 20 minutes.
TP20	21/02/2019	2.3	Groundwater seepage encountered at 2.3m. Not sufficient to fill the pit.
DTS04	18/02/2019 04/03/2019 20/03/2019 01/04/2019	3.97 1.3 Dry Dry	Groundwater level measured during monitoring visit.
DTS06	18/02/2019 04/03/2019 20/03/2019 01/04/2019	Dry 2.7 Dry 2.62	Groundwater level measured during monitoring visit.
DTS13	18/02/2019 04/03/2019 20/03/2019 01/04/2019	Dry 3.98 Dry Dry	Groundwater level measured during monitoring visit.
DTS19	18/02/2019 04/03/2019 20/03/2019 01/04/2019	3.16 3.05 3.1 3.1	Groundwater level measured during monitoring visit.
Table 6.4.1			

6.4.2 It should be noted that water levels will vary depending generally on recent weather conditions and only long-term monitoring of levels in standpipes will provide a measure of seasonal variations in groundwater levels.

6.5 Evidence of contamination

6.5.1 During the excavation of our exploratory points, other than the presence of Made Ground within Zones 1, 2 and 4, the only other evidence of potential contamination was related to hydrocarbon odours noted within such deposits in trial pit TP05 between depths of 1.9-3.4m.

6.6 Obstructions and instability

6.6.1 The following table summarises obstructions and instability encountered during our exploratory excavations;

Table summarising obstructions and instability observations		
Exploratory point	**Depth of obstruction**	**Description of obstruction and/or instability**
DTS01	3.5m	Obstruction at the base of exploratory hole, possibly timber.
DTS03	2.3m	Obstruction at the base of exploratory hole, anticipated bedrock encountered
DTS06	3.0m	
DTS07	0.88m	
DTS09	0.60m	
DTS10	3.0m	
DTS11	1.57m	
DTS12	2.40m	
DTS15	1.52m	
DTS16	2.60m	
DTS17	3.60m	
DTS19	5.43m	
DTS22	5.42m	
DTS26	3.30m	
DTS28	2.80m	
TP01	1.20m	
TP02	2.60m	
TP03	1.70m	
TP04	1.00m	
TP08	3.30m	
TP10	3.50m	
TP11	1.20m	
TP13	1.00m	
TP03	0.4m	Collapse of trial pit sides from 0.4m to 0.7m depth on eastern wall, widening trial pit by 0.3m.
TP06	0.0m	Collapse of trial pit sides from 0.0m to 1.9m depth, widening trial pit by 0.25m each side.
TP07	0.3m	Collapse of trial pit sides from 0.3m to 3.7m depth on southern wall, widening trial pit by 0.3m.
TP09	1.3m	Collapse of trial pit sides from 1.3m to 2.0m depth on southern wall, widening trial pit by 0.2m.
TP10	1.0m	Collapse of trial pit sides from 1.0m to 3.0m depth, widening trial pit by 0.5m each side.
TP14	2.2m	Collapse of trial pit sides from 2.2m to 3.4m depth, widening trial pit by 0.3m each side.
TP15	0.3m	Collapse of trial pit sides from 0.3m to 3.5m depth, widening trial pit by 0.3m on eastern and western sides.
TP16	0.1m	Collapse of trial pit sides from all directions, widening trial pit by 0.1 to 0.2m
TP20	0.2m	Collapse of trial pit sides from 0.2m to 1.0m and 2.2m to 3.0m depth, widening trial pit by 0.2-0.25m each side.
Table 6.6.1		

7 Geotechnical Appraisal

7.1 General description of the development

7.1.1 The following assessments are made on the investigatory data presented in the preceding sections of this report and are made with reference to specific nature of the development. Should scheme proposals change then it may be necessary to review the investigation and report.

7.1.2 Based on updated sketch layouts, we understand the scheme will comprise the construction of a large number of dwellings, together with associated gardens, infrastructure and access roads constructed to standards allowing adoption by the local highway authority. Preliminary development proposals are presented in Appendix O. Following previous reporting and recent discussions with the client, it is understood that the former landfill area referred to as Zone 1 will not be developed, and layout/reprofiling of more developable areas of the site has been optimised accordingly. The following assessment has been updated to reflect this.

7.2 Building regulations and this report section

7.2.1 Building Regulations

7.2.1.1 Current Approved Document A of the building Regulations references Eurocodes and their UK National Annexes as practical guidance in meeting part A requirements. Approved document A advises there may be alternative ways of achieving compliance with requirements where it can be demonstrated that the use of withdrawn standards no longer maintained by the British Standards Institution continues to meet Part A requirements.

7.2.2 This report section

7.2.2.1 This chapter of the report provides a foundation strategy for the proposed development based on 'Traditional Methods' which relate (in part) to withdrawn British Standards. However, a number of the geotechnical design parameters comply with Eurocode 7 (BSEN1997-1:2004 '*Geotechnical Design – part 1 General Rules'* and the corresponding UK National Annex). We can provide a full foundation strategy based on Eurocode 7 where required. It is for the foundation designer to select the design methodology and demonstrate compliance with part A requirements.

7.2.3 Geotechnical terms

7.2.3.1 Definitions of geotechnical terms used in the following paragraphs are provided in Appendix A.

7.2.4 Foundation solutions

7.2.4.1 Due to the complex nature of soils encountered across the site, and for ease/clarity, we have provided specific foundation assessments in the following paragraphs for each of the zones as presented on Drawing 04, with the exception of Zone 1 for reasons as described in paragraph 7.1.2 above. We have also provided a foundation zoning plan, presented on Drawing 09, to assist in the interpretation of the following assessments.

7.3 Zone 1 (north-western part of the site)

7.3.1 Ground conditions

7.3.1.1 A detailed summary of ground conditions is provided in Section 6. In summary, significant deposits of Made Ground were encountered in this area of the site, consistent with landfilling as recorded by Envirocheck, which appeared to be of 1950-80s origin. Soils typically comprised of coarse angular bricks, concrete, glass, plastic, metal wire, vehicle parts, shoes, paper, timber ceramic tiles, roof tiles and slag. The full thickness of Made Ground was not proven in this area of the site. Perched groundwater was encountered locally within deposits of Made Ground.

7.3.1.2 It should be noted that a western half of this area of the site could not be investigated due to the presence of a construction site associated with the adjacent railway. Based on desk study information presented in Section 3, it is likely that the landfill material encountered to the east, extends across the entire area and is likely to be consistent.

7.3.2 Foundation solution

7.3.2.1 Based on the updated layout provided by the Client, development is no longer planned for Zone 1, largely due to the above ground conditions encountered. Therefore, we have not provided a foundation strategy for this area.

7.4 Zone 2 (south-western part of the site)

7.4.1 Ground conditions

7.4.1.1 In summary, significant deposits of Made Ground were encountered in large portions of this part of the site, consistent in part with that encountered in Zone 1, but included increased volumes of slag, brick, coal and glass and was typically much ashier in composition. This is likely to be a result of the terracing that this area of the site has been subject to historically, in addition the presence of a small area of landfill on the existing recreational ground as recorded by the Local Authority. Made Ground was encountered to depths >3m in such areas of the site.

7.4.1.2 Locally, the full thickness of Made Ground deposits and possible reworked natural soils was proven, between depths of 1m to 2.7m below existing surface levels. Below such deposits, weathered deposits of Bowland Shale Formation were encountered, typically consisting of medium dense orangish brown SAND medium dense grey GRAVEL of angular limestone, sandstone or shale. Natural Bowland Shale to the southern area of Zone 2 typically comprised of medium to high strength clays.

7.4.2 Foundation solution

7.4.2.1 In view of the depth, apparent variation in the compaction, and composition of the near surface Made Ground deposits, such soils in our opinion are incapable of supporting concentrated foundation loads without promoting excessive amounts of total and differential settlements outside recognised limits for the proposed buildings. We have therefore identified other foundation options as described below.

7.4.2.2 Due to the composition of such soils they are not considered to be amenable to improvement using vibrotreatment techniques, or any other technique which would otherwise have the effect of increasing the density of the Made Ground.

7.4.2.3 In addition, we do not consider a raft foundation feasible due to the compaction, and composition of Made Ground and the likely long term degradation of deposits which will promote collapse settlement.

7.4.2.4 In areas of deep Made Ground a piled foundation is recommended. A piled foundation would transmit superstructural loads down through the Made Ground into the Bowland Shale Formation at depth to obtain end bearing and shaft adhesion support. A supplementary borehole investigation should be carried out to explore ground conditions at depths beyond possible pile lengths in such areas.

7.4.2.5 Based on the preliminary foundation zoning plan presented on Drawing 09, Plots 178 to 184, 223 to 246 and 261 to 267 will require piled foundations. It is noted that granular deposits in the area of trial pit TP15 are recorded as natural, however, significant collapse of trench sides occurred during excavations. We have therefore considered this area with deeper Made Ground and requirement for piled foundations, given deposits are likely to be loose and unsuitable for more traditional foundations. Further intrusive investigations would need to be undertaken to confirm this.

7.4.2.6 In the area of Plots 178 to 222, 247 to 260, 268 to 283, traditional concrete trench fill foundations could be adopted, founding on deposits of weathered Bowland Shale Formation at depth. Foundations would need to be deepened through any Made Ground and reworked natural soils and extend into the naturally deposits soils by a minimum of 0.3m, subject to an overall minimum foundation depth of 1.0m (based on laboratory determination of plasticity). Bearing capacities are provided in Section 7.7 below.

7.4.2.7 Typically, based on recorded depths of Made Ground and reworked natural soils, trench fill foundations in the area of Plots 185 to 222 would need to be excavated to depths of between 1.3 to 2.0m below existing surface levels. In the area of Plots 247 to 260 and 268 to 283, trench fill foundations would need to be excavated to depths of 2.2m to 2.7m. Whilst technically feasible, consideration will need to be given to the stability of Made Ground deposits where foundation excavations exceed depths of 2m, and the possible requirement for shoring. It is considered unlikely that significant groundwater/perched groundwater inflows would be encountered in such areas of the site based on investigations to date. Further intrusive investigations would need to be undertaken to confirm this.

7.4.2.8 Based on the cut and fill that is proposed at present (refer to Appendix N), there is likely to be a marginal degree of cut (~0.5m-1.0m) in areas of the site where trench fill foundations could be adopted. This will assist with reducing thicknesses of Made Ground/reworked soils and thus overall foundations depths (providing the minimum depth as defined above is achieved).

7.4.2.9 It should be noted that there are a number of trees and major vegetation in this area of the site which may require foundation depths exceeding the minimum depth defined above. Further guidance on this is provided in the following report paragraphs.

7.4.2.10 With reference to the site history presented in Section 3.4, this part of the site was subject to significant development associated with railway infrastructure. Consideration should be given to the possibility that underground structures may be present locally which have not been encountered to date and could influence the development.

7.5 Zone 3 (central part of the site)

7.5.1 Ground conditions

7.5.1.1 In summary, Weathered Eyam Limestone Formation was generally encountered in Zone 3, with a covering of Topsoil some 0.3m thick on average. Eyam limestone was typically encountered as medium dense brown SAND or very sandy GRAVEL of sandstone and shale in the northern parts of Zone 3, and across the rest of the area as firm to stiff low to medium strength sandy gravelly CLAY.

7.5.1.2 In eastern parts of Zone 3, in the areas of DTS10, DTS17, DTS28, TP06, weathered Bowland Shale Formation deposits were present, typically comprising of medium to high strength CLAY and GRAVELS of angular mudstone and shale.

7.5.1.3 Generally, the majority of excavations in Zone 3, with the exception of TP06, terminated on deposits of suspected bedrock between depths of 0.6m to 3.9m below surface levels. We have presented contour plots on Drawings 05a and 05b which indicate the depths at which bedrock has been encountered within Zone 3, in mbgl and mAOD respectively.

7.5.2 Foundation solution

7.5.2.1 In our opinion naturally deposited Weathered Eyam Limestone Formation in Zone 3 will adequately support proposed buildings on concrete strip/trench fill foundations. Based on laboratory determination of plasticity and following National House Building Council (NHBC) Standards Chapter 4.2, we recommend foundations extend to a minimum depth of 0.9m below existing or proposed ground levels whichever gives the deeper founding level. Bearing capacities are provided in Section 7.7 below.

7.5.2.2 With reference to Drawing 09, due to the presence of near surface clays, which exhibit a combination of low shear strengths (typically <25kN/m^2) and SPT N Values (typically <2), foundations in the area of Plots 33 to 36 and 100 to 155 will require deepening, with excavations taken down to depths of between 1.2m to 1.7m below existing surface level. Further intrusive investigations would need to be undertaken to confirm this.

7.5.2.3 With reference to the bedrock contour plots presented on Drawings 05a and 05b, where foundation excavations require depending, there is the possibility that bedrock could be encountered in the base of excavations, or a combination of bedrock and weathered Eyam Limestone Formation deposits. In such instances, we would recommend that all excavations are located on bedrock to minimise the effects of differential settlement.

7.5.2.4 Furthermore, in central parts of Zone 3 (TP04 and DTS07 and DTS09), bedrock has been encountered at depths of between 0.6m to 1.0m below existing surface levels. Consideration will need to be given to the requirement to excavate into bedrock in such areas of the site. Where bedrock is present at depths shallower than the minimum foundation depth defined in paragraph 7.5.2.1 above, excavations could be reduced, providing sufficient penetration into bedrock is obtained in order to 'key' in the base of the foundation. Again, as described in paragraph 7.5.2.3, if a combination of bedrock and weathered Eyam Limestone Formation deposits is present in the base of foundation excavations, we would recommend that all excavations are located on bedrock to minimise the effects of differential settlement.

7.5.2.5 Based on the proposed cut and fill, there is likely to be a large amount of cut (up to 3m in places) undertaken across central areas of Zone 3. This is likely to assist with reducing thicknesses of unsuitable founding strata in the area of Plots 100-155, and thus overall foundations depths (providing the minimum depth as defined above is achieved unless bedrock is encountered). In addition, consideration will need to be given to the requirement for use of breaking equipment to facilitate cut where bedrock is present. The contour plot presented on Drawing 05c shows the likely extent of cut required into bedrock based on current and proposed levels. This will assist in determining the volume of proposed cut located in areas of bedrock.

7.5.2.6 It should be noted that there are a number of trees and major vegetation which border this area of the site which may require foundation depths exceeding the minimum depth defined above. Further guidance on this is provided in the following report paragraphs.

7.6 Zone 4 (eastern part of the site)

7.6.1 Ground conditions

7.6.1.1 At present we have been unable to confirm ground conditions in the northern part of Zone 4 due to access restrictions. Where access was available in the southern half of Zone 4, ground conditions were variable. Made Ground was encountered to depths of 1.3m in DTS13, 1.6m in TP08 and 3.0m in DTS18 and was similar in composition to that encountered in Zone 2, comprising of granular material with gravels of slag, brick, coal and glass, textile, timber, plastic and metal. The exception was TP13, which encountered Topsoil onto naturally deposited Weathered Bee Low Limestone Formation comprising orange brown slightly clayey sand. TP13 terminated on what is suspected to be bedrock, located at depths of 1.0m below surface level.

7.6.1.2 Locally, in boreholes DTS18 and DTS102, deposits of suspected reworked Weathered Bee Low Limestone Formation were present, extending beyond termination depths of the boreholes (>5-5.45m). Such deposits regularly exhibited a combination of low shear strengths (typically <20kN/m^2) and SPT N Values (typically <2, often 0), which would suggest the presence of voiding or poorly compacted soils. Elsewhere, naturally deposited Weathered Bee Low Limestone Formation was present below Made Ground, comprising of medium dense orangish brown slightly silty fine SAND or stiff high strength orangish brown sandy CLAY.

7.6.2 Foundation solution

7.6.2.1 Based on development proposals, Plots 1 to 12 are located in Zone 4, and within the area that was not accessible at the time of our investigation. Given the variable nature of ground conditions encountered in the accessible areas of this part of the site, we recommend that further plot specific intrusive investigations are undertaken to confirm the composition of soils. Particularly given that a shallow bathing lake feature was recorded in this area of the site historically (known as 'Russia Mere').

7.6.2.2 Based on excavations completed to date, it is possible that at the very least, deeper traditional trench fill foundations would be required, located on naturally deposited Weathered Bee Low Limestone Formation at depth. Given the presence of suspected reworked Weathered Bee Low Limestone Formation adjacent to the east of Plots 1 to 12 (refer to Roundabout G02 report for further details), there could also be the possibility that plots will require piled foundations. At present, consideration of a worst-case scenario is likely to be sensible. Bearing capacities for trench fill foundations located on naturally deposited Weathered Bee Low Limestone Formation are provided in Section 7.7 below.

7.6.2.3 Based on the proposed cut and fill, there is likely to be a marginal degree of cut (~0.5m-1.0m) in this area of the site, if deeper trench fill foundations are required, this will assist with reducing thicknesses of Made Ground/reworked soils and thus overall foundations depths.

7.7 Determination of preliminary bearing capacities using pre-Eurocode 7 methods

7.7.1 The following paragraphs derive preliminary bearing capacities using 'traditional' techniques adopting global factors of safety against failure where experience shows has worked well, and are considered appropriate to satisfy part A of the building regulations. These should be considered preliminary and should be verified with further plot specific investigation as outlined in preceding paragraphs once development proposals are finalised.

7.7.2 Due to the variable nature of the near surface naturally deposited weathered Bowland Shale, Weathered Eyam Limestone Formation and Weathered Bee Low Limestone Formation, our foundation assessments take into consideration the effects of both cohesive (clays) and granular (sands/gravels) soils. Bearing pressures outlined in the following paragraphs are considered preliminary and are based on providing values for clay soils at the site, as in this instance they typically yield more conservative bearing capacities than those for granular soils at the site. However, the effects of both soil types are taken into consideration in the assessment of differential settlement. Foundation depths within each of the assessed Zones are outlined in sections 7.3 to 7.5 above. This provides a worst case scenario for the site.

7.7.3 Based on the results of the investigations, and adopting a cohesive ground model for the site, we have adopted a characteristic undrained shear strength (C_u) for soils below and around likely foundation levels of 50kN/m^2 based on the results of field measurements (refer Appendix C2), and our experience. Calculations indicate following preliminary bearing values for varying width concrete trench fill/ strip foundations: -

Table of preliminary bearing values for traditional strip/trench fill foundations

Width (m)	Ultimate bearing value kN/m^2	Presumed bearing value kN/m^2	Allowable bearing pressure kN/m^2
0.45	350	125	125
0.6	330	120	120
0.75	320	115	115
1.0	310	110	110

Table 7.7.3

7.7.4 The presumed bearing value has been derived from the ultimate bearing value by applying a factor of safety of 3, and the allowable bearing pressure derived to limit total settlement to 25mm.

7.7.5 It is difficult to accurately predict the amount of total and differential movement caused by consolidation of the foundation supporting subsoils, however, providing the foundation loads do not exceed the allowable bearing pressure provided in the preceding paragraphs, we suggest total settlement will be small, and probably less than 25mm. It is likely settlement will be substantially achieved within say 10-15 years of construction. If stresses applied at foundation formation levels vary significantly then this will increase levels of differential settlement produced by variation in ground conditions alone.

7.7.6 Based on the table above, we would recommend that further onsite trial pit/ borehole investigations are undertaken to confirm foundation requirements on a plot specific basis once development proposals are finalised.

7.8 Influence of trees and other major vegetation

7.8.1 Soil classification and new foundation design

7.8.1.1 The results of plastic and liquid limit determinations performed on samples of the, weathered Bowland Shale Formation and weathered Eyam Limestone Formation (form Zones 2 and 3) indicate these deposits are soils of high and medium volume change potential respectively when classified in accordance with National House Building Council (NHBC) Standards, Chapter 4.2. Foundations taken down onto a depth of 1.0m (for high) and 0.9m (for medium) will penetrate the zone of shrinkage and swelling caused by seasonal wetting and drying. Trees and other major vegetation extend this zone and will require deeper foundations. A good guide to this subject is provided in NHBC Standards, Chapter 4.2.

7.8.2 Tree species identification

7.8.2.1 There are a number of trees and other major vegetation at the site (and adjacent to the site). On this basis it will be necessary to appoint a qualified Arboriculturist (listed in the Arboricultural Association Directory of Consultants – www.trees.org.uk) to determine the location, height (and mature height) and water demand of all trees/major hedgerows at and close to the site, information, which will be necessary to design foundations in accordance with NHBC Standards, Chapter 4.2.

7.8.3 New planting

7.8.3.1 Any planting schemes should also take into account the effect that new trees could have on foundations when they reach maturity. Again, a good guide to this subject is provided in NHBC Standards, Chapter 4.2.

7.9 Ground Floor Construction

7.9.1 Ground bearing floor slabs can be adopted in Zone 3 at this site where buildings are remote from trees and where Topsoil deposits are fully removed within the footprint of the building. We recommend a blanket of good quality compacted granular material be placed prior to construction of the floor slabs.

7.9.2 Due to the thickness of Made Ground deposits present in Zone 2 (unless proposed cut removes all Made Ground) and the likelihood that Made Ground or reworked soils are present in Zone 4 in the area of Plots 1 to 12, we recommend a suspended ground floor is adopted.

7.9.3 Furthermore, in areas close to existing major vegetation at the site (or where ground floors are elevated requiring in excess of 600mm of fills) then we recommend the use of a suspended ground floor with a sub floor void determined following NHBC Standards, Chapter 4.2.

7.10 Requirements for steel reinforcement in building foundations

7.10.1 Based on observations in trial pit excavations, it is likely that excavations to founding levels will encounter both fine grained (clay type) and coarse grained (granular) soils. Whilst these soils will ultimately generate similar amounts of total settlement under applied foundation loads, the rate at which settlement will be achieved will differ. Granular soils will produce settlements almost immediately loads are applied, with fine grained (clay type) soils generating settlement sometime after completion of construction. Thus foundations (particularly strip / trench fill concrete foundations) traversing differing soil types will be subject to some differential settlements due to differing rates at which total settlement will be achieved. To minimise the effects of such differing rates of settlement we recommend foundations are reinforced to stiffen concrete and thus resist the effects of differential movement where foundations traverse cohesive and granular soils. In the event that a soft area is located in the course of foundation excavations then we recommend excavations continue to locate stiffer/denser soils.

7.10.2 It is understood that due to the possible risks of dissolution of the underlying limestone at the site (refer to Section 7.12 below), any strip/trench fill foundations at the site will be significantly reinforced as a matter of course, subject to Local Authority approval.

7.11 Foundation and service trench stability and excavation considerations

7.11.1 Based on our observations of the stability of the sides of trial pit excavations in Made Ground in Zone 2 we consider there is a possibility of some over break/instability in the sides of foundation excavations, particularly where excavations are deepened through more significant deposits of Made Ground. Such excavations are likely to require shoring to maintain an open excavation.

7.11.2 In addition, instability was also observed locally (TP03 and TP06) in near surface weathered Eyam Limestone Formation in Zone 3 between depths of 0.7m and 1.9m. consideration should be given to the requirement of localised shoring in such areas.

7.11.3 Typically, groundwater observations in natural soils suggest that levels are remote from founding depths and located at depths of around 2-3m. Beyond this depth the risks of encountering groundwater increase significantly with groundwater inflows promoting collapse of trench sides and the construction of a successful spread type foundation difficult. Locally, adjacent to Nun Brook, groundwater levels were measured within 2m of surface level. It is likely that in such areas of the site, the groundwater is in continuity with the level in the book. Perched water was also present locally in Made Ground deposits. We anticipate any water will be controlled with nominal pumping techniques.

7.11.4 As indicated in Section 7.5 above, excavations in Zone 3, and to a lesser extent in Zone 4, are at risk of encountering limestone bedrock, particularly during cut and fill works. Consideration will need to be given to the requirement for use of breaking equipment to loosen the deposit prior to excavation. Given the cut depths of up to 3m are likely in Zone 3, we consider this a high possibility and consideration of difficulty of excavation within the bedrock will be required.

7.11.5 We recommend any trench excavation requiring human entry is shored as necessary to conform with current best practice, and accepted by the Health and safety Executive (HSE) and in particular, following guidance provided in the HSE publication '*Health and safety in construction (HSG 150)*' (www.hse.gov.uk).

7.12 Slope stability

7.12.1 Existing slope stability

7.12.1.1 Based on topographical survey data, site levels fall towards Nun brook in the centre of the site, at inclinations of around 20° in Zone 3. It is also noted that the BGS map for the area records the Eyam Limestone within Zone 3 to dip at 22° to the north-west/west, consistent with surface levels. Although the area is not recorded as a landslip site on geological maps and Envirocheck data (refer to Appendix M for latter), and during our site reconnaissance no signs of instability was noted, due to the relatively steep dip of bedrock, consideration should be given to the potential risk of natural slope instability during construction works.

7.12.2 Slope stability during and following construction

7.12.2.1 Based on current earthworks proposals, whilst large areas of limestone in Zone 3 are weathered to clays and granular material, significant areas of cut are likely in areas of limestone bedrock. Based on the dip orientation of limestone in Zone 3, it is likely that excavations will be undertaken perpendicular to the dip. Given the typical jointed and fractured nature of limestone, in addition to the severity of dip, slippage of rock mass may occur along bedding planes at the face of the cuttings. This may also occur within foundation trench excavations. As a consequence, assuming that limestone does dip at the angle as indicated above, we would recommend the following outline restraints be imposed on the development to minimise the risk of mass block failure: -

a) The length of open trench excavations (for foundations and service installations) following ground contours shall not exceed say 10m and a gap of at least 20m shall be provided between adjacent excavations following ground contours.

b) No permanent cuttings following ground contours shall extend more than say 1m into the limestone bedrock.

c) Filling parts of the site following ground contours shall not exceed 1m and this includes temporary spoil heaps.

d) Concentrated infiltration into limestone bedrock is minimised, which would otherwise also act as a possible mechanism for dissolution

7.13 Dissolution features

7.13.1 Eyam Limestone and Bee Low Limestone present in Zones 3, 4 and 5 at the site are typically rich in Calcium Carbonate. CIRIA reports PR11 and C574 (relating to chalk sites) states 'The presence of dissolution features should be expected on all calcium carbonate rich sites'. Dissolution features in general comprise the following:

- Sinkhole, formed by dissolution of near surface limestone reducing their volume and creating a surface depression.
- Dissolution pipe, a cone or pipe like cavity typically in filled with limestone which has subsided into the cavity, with the infill limestone much weaker than the surrounding.
- Swallow holes, a surface feature where a void in the limestone continuously or intermittently 'swallows' wholly or partially a surface stream.

7.13.2 Assessment of the risk to foundations posed by dissolution features

7.13.2.1 Dissolution features pose a hazard to foundations because of the presence of one or more of the following:

1. Large variations in intact limestone horizon
2. Loose limestone or superficial deposits infilling pipes
3. Cavities or caves within the limestone
4. Dissolution widened discontinuities in the limestone affecting its load carrying capacity

These features are generally located above the groundwater table level.

7.13.2.2 Clearly the risk that these hazards present to a building relates to its vulnerability, which in turn relates to the foundation type. A building on shallow spread type foundations and ground bearing floors is more vulnerable than piled foundations extending through the base of these features supporting a suspended ground floor slab.

7.13.2.3 Research suggests that the majority of recent occurrences of ground subsidence was induced by man. The most common activities triggering subsidence are as follows: -

- Dynamic and static loading
- Leaking drains
- Leaking water supply pipes
- Water flows from soakaways
- Overzealous garden watering in dry weather

7.13.3 Risk assessment and mitigation

7.13.3.1 Unfortunately in many cases it is not possible to confidently discount the presence of dissolution features, but we have assessed the risk based on the following: -

Item	Observation / enquiry	Assessed risk
Surface features	No obvious evidence of any surface depressions in topography local to the site. Although Envirocheck record a natural sink hole and solution pipe 596m to the SE.	Low-moderate
Variation in density of near surface soils	It was noted during site investigations that localised areas of near surface weathered Eyam Limestone in Zone 3 exhibited very low shear strengths and SPT N Values. This appears to be consistent with the zone of moderate to high risk of dissolution as recorded by Envirocheck (refer to Drawings 03 and 09 for details). Furthermore, there was a significant variation in the thickness of more weathered deposits overlying bedrock in Zone 3.	Moderate
Variation in intact limestone horizon	No significant penetration was gained into limestone deposits to assess this.	Unknown
Adverse movement in nearby buildings	No adverse movement in neighbouring properties close to the site (viewed from public roads / footways only).	Low
Envirocheck data base	Assessed risk considered moderate to high within Zone 3 – refer to Drawings 03 and 09 for zone of dissolution.	Moderate-high
Enquiries to local authority building control and NHBC	High Peak Borough Council have been contacted but are yet to respond to our enquiry. The client has been able to contact NHBC for advice. They have indicated that in such areas they would typically require plots to be founded on raft foundations. Further probe holes would typically be required to confirm that presence, or otherwise, of dissolution features and depth to bedrock, following which reinforced trench fill foundations could be adopted rather than rafts.	Moderate-high

Table 7.13.3

7.13.3.2 Based on the above, the risk of the site being subject to the effects of dissolution features is considered moderate to high.

7.13.4 Risk mitigation measures

7.13.4.1 We therefore recommend that non-intrusive geophysical surveys are undertaken by a specialist across the area of Zones 3 and 4 to determine if there are any anomalies near surface which could indicate the presence of such features.

7.13.4.2 Regardless of the outcome of the above, it is likely that plots located directly on limestone bedrock would not require mitigation measures incorporated within the foundation design.

7.13.4.3 Typically NHBC and Local Authority Building Control would expect to see the use of stiff raft foundations in such areas to resist any loss of ground support due to dissolution. It is understood that due to the severity of the surface levels within Zone 3, the construction of raft foundations is likely to be difficult to successfully achieve. A highly reinforced trench fill/strip foundation is likely to be considered acceptable by the NHBC, subject to further plot specific investigations being undertaken to confirm the competency of underlying soils.

7.13.4.4 As infiltration systems may be utilised at the site, we recommend water is not concentrated in isolated locations but evenly distributed in say level trench type soakaways to minimise the risk of promoting the formation of dissolution features. Again, such soakaways need to be positioned remote from buildings and remote from settlement sensitive features.

7.13.4.5 Water supply pipes need to be watertight and flexible to minimise risks of leaks. Heavy vibration from compaction plant shall not be used.

7.14 Infiltration potential

7.14.1 Contamination considerations

7.14.1.1 With reference to Environment Agency (EA) publication '*Groundwater protection: Policy and practice (GP3) Section G,* 2012, outside of SPZ1, the EA will support sustainable drainage systems for new discharges to ground. This is subject to an appropriate risk assessment to demonstrate that ground conditions are suitable and infiltration systems do not present an unacceptable risk of promoting mobilisation of contaminants or creating new pathways for contaminant migration.

7.14.1.2 The permeability of the near surface weathered Eyam Limestone, Bowland shale and Bee low Limestone Formation in combination with the site located over Secondary A (Bowland Shale) and principal aquifers (limestone deposits) suggests the site is sensitive to migration of contaminants. The site is not located within or close to a source protection zone. Providing that surface water is restricted from freely migrating though Made Ground deposits, the risk of infiltration systems promoting mobilisation of contaminants at the site is considered low. All discharges to groundwater are subject to compliance with the Water Framework Directive (2000/60/EC) and Groundwater Daughter Directive (2006/118/EC).

7.14.2 Requirements for use of infiltration systems

7.14.2.1 It is a requirement under H3 (3) of the current building regulations to discharge stormwater collected by a development to soakaways as a priority (as opposed to water courses and sewers)

7.14.3 Infiltration measurements

7.14.3.1 The permeability of the weathered Bee Low Limestone and weathered Eyam Limestone Formations was measured in boreholes DTS06 and DTS13 respectively, following the principles described in Building Research Establishment (BRE) Digest 365 (2016) "*Soakaway Design*". Tests were carried out between depths of 1.87m and 3.0m in DTS06 (deposits of clay) and 1.75m and 3.89m in DTS13 (deposits of clay), providing infiltration rates of 3.81 x 10^{-6} m/s in DTS06 and between 2.67 x 10^{-4} m/s and 4.72 x 10^{-5} m/s in DTS13. Records of testing and calculations are presented in Appendix C3.

7.14.3.2 It should be noted that testing has not been strictly carried out in accordance with the BRE publication, as the minimum size of the test hole (BRE 365 states that the trial pit should be 0.3 to 1 m wide and 1 to 3 m long and should have vertical sides trimmed square) could not be achieved in the borehole, however the test provides an indication of the likely permeability of the soils under test. Further on-site testing is recommended using machine dug trial pits to allow test procedures to conform with the requirements of BRE digest 365. We can carry out such testing on further instructions.

7.14.3.3 The indicative permeability of weathered Bowland Shale Formation deposits was measured using falling head tests carried out in borehole DTS19 (gravels) following the Hvorslev method as defined in BS EN ISO 22282-2:2012. Records of the test results and calculations to determine the soil infiltration rate is presented in Appendix C3. The testing provided an indicative permeability between 2.94 x 10^{-6} m/s to 3.12 x 10^{-6} m/s.

7.14.4 Design of infiltration systems

7.14.4.1 With regard to the deposits of reworked weathered Bee Low Limestone Formation (refer to Section 7.15 for further details), there is evidence of possible voiding and poor compaction within soils. Such deposits will exhibit a varying degree of permeability and potentially will be able to dispose of stormwater using infiltration systems. Such a method of stormwater disposal does have the following potential drawbacks: -

- Water freely/directly discharged into the reworked soils could cause collapse of air voids contained in these deposits, which promotes compaction of the soils around the soakaway causing depression of the general area around the soakaway as well as potentially affecting pipe runs leading to the soakaway.

- Water freely/directly discharged into soils close to cutting slopes could promote instability of such slopes. Typically, railway companies (possible adjacent land owners) restrict the use of soakaways close to their land boundaries.

7.14.4.2 Naturally deposited soils exhibit some variation in composition across the site and thus likely permeability. On this basis the use of trench type soakaways will increase the likelihood of locating more permeable soils along its length and by evenly distributing stormwater along their length minimise the risk of promoting formation of solution cavities.

7.14.4.3 Testing completed to date should be considered preliminary only and we recommend further, more intensive, on site testing is carried out targeting this part of the investigation allowing detailed design of infiltration systems to be progressed if such systems are to be adopted.

7.14.4.4 If infiltration systems are adopted as a means of stormwater disposal (including permeable pavement construction), we recommend approval for the use of soakaways is sought from the Environment Agency. It should be noted that the Groundwater Regulations 1998 require that list 1 substances (e.g. Hydrocarbons) are to be prevented from entering groundwater receptors and list 2 substances (e.g. metals) are also restricted. Typically, the Environment Agency will require details of the proposed soakaway systems, showing pollution prevention measures. They will also require geological and geo-hydrological information, (contained in this report) as well as the risks of chemical contaminants in the ground affecting water resources. It is also typical requirement that there is an 'unsaturated zone' between the base of the soakaway system and the groundwater table (saturated zone) providing attenuation capacity.

7.15 Pavement foundations

7.15.1 Criteria for design of the pavement foundation

7.15.1.1 The thickness of the pavement foundation (typically unbound granular materials- or sub-base and capping materials) is derived from a combination of the following:

- Number of passes of standard (80kN) axles from construction traffic (HGV). i.e. construction traffic loading which the foundation is required to carry.
- The location of the water table.
- Weather conditions at the time of construction.
- The strength of the subgrade, determined by measurement of the California Bearing Ratio (CBR).

7.15.1.2 For road designs meeting the requirements of the Highways Agency, then subgrade CBR will derive a foundation layer thickness relating to differing subgrade stiffness's. (refer interim advice note 73/06).

7.15.2 Methods of determination of CBR values

7.15.2.1 The following table identifies common methods of determination of CBR values

Common methods of CBR determination				
Method	**reference**	**Outline methodology**	**Advantages**	**Disadvantages**
Direct on soil in CBR mould	BS1377 and Interim advice note 73/06 (2009)	Soil sample in steel mould. Can be undisturbed or disturbed (recompacted in mould). Load measured to force 50mm diameter steel plunger 2.5 and 5mm into soil to derive CBR	BS procedure Department for transport procedure	CBR measured at water content at time of test. CBR may not reflect changes in water content during life of pavement. Unsuitable for very coarse grained (> 20mm) soils
Plate bearing test	Interim advice note 73/06 (2009)	Load required to displace a 762mm diameter steel plate 1.25mm into the subgrade to derive a CBR	Department for transport procedure. Suitable for coarse grained soils	CBR measured at water content at time of test. CBR may not reflect changes in water content during life of pavement. Reasonably slow procedure.
Dynamic cone	Interim advice note 73/06 (2009)	Record number of blows of 8kg drop weight falling 575mm to drive 20mm 60-degree steel cone 50 to 550mm into the subgrade.	Department for transport procedure. Reasonably rapid assessment.	CBR measured at water content at time of test. CBR may not reflect changes in water content during life of pavement. Unsuitable for very coarse-grained soils
Soil classification characteristics	LR 1132 structural design of bituminous roads (Transport Research laboratory)	Measurement of plasticity or particle side distributions, and knowledge of location of water table required to derive CBR for varying construction conditions	CBR derive for subgrade during life of pavement. Simple testing. Relates to long term research and experience at the TRL	Interim Advice note 73/06 (section 5.5) says this should only be used samples cannot be taken for laboratory testing.
Undrained shear strength	TRRL report 889 Strength of clay fill subgrades: its prediction in relation to road performance.	CBR = Cu/23, where Cu is the undrained shear strength (kN/m2).	Cu could be measured by hand held shear vane rapidly and in great quantities. Relates to long term research and experience at the TRL	Cu measured at water content at time of test. Derived CBR may not reflect changes in water content during life of pavement. Unsuitable for coarse grained soils

Table 7.15.2

7.15.2.2 Methodology can sometimes be dictated by design manuals of a local highway authority who may adopt the road network and would probably favour methods described in Interim advice note 73/06.

7.15.3 Location of the pavement formation

7.15.3.1 For the purposes of the following assessment we have reviewed likely formation strata in each of the specific developable zones (2-4) on the residential site as indicated on Drawing 04. We anticipate that proposed access roads and associated hardstanding areas within each zone will be located at or about existing ground levels with formation located on the following soils: -

- Zone 2 – Made Ground (landfill type material) and general Made Ground with anthropogenic material
- Zone 3 – Weathered Eyam Limestone Formation
- Zone 4 – Typically Made Ground (landfill type material) as per Zone 2 (and Zone 1), in addition to very locally reworked Bee Low Limestone Formation and naturally deposited Bee Low Limestone Formation.

7.15.3.2 It should be noted that proposals include a significant cut and fill exercise across the site, which is likely to alter the composition and strength/density of subgrade below proposed roads/hardstanding. We have based the following CBR assessment on current condition of soils at likely formation levels below existing surface level. Reassessment of such values will be required following finalisation of cut and fill works across the site. Clearly, in areas of significant fill, the compaction achieved on such material will dictate overall subgrade CBR value.

7.15.4 Zone 2 (south-western part of the site) and Zone 4 (eastern part of the site)

7.15.4.1 Equilibrium CBR (California Bearing Ratio) values (with reference to Transport and Road Research Laboratory (TRRL) Report LR1132 '*Structural design of Bituminous Roads*') are derived from knowledge of soil classification data (plasticity index for soils exhibiting cohesion (clay type) and particle size distribution for granular soils), the location of the water table pavement thickness, and weather conditions at the time of construction. It is anticipated that excavations to formation levels will encounter a mixture of both granular and cohesive soils. Granular soils will provide numerically high CBR values, but cohesive soils will typically provide significantly lower values.

7.15.4.2 It is possible to derive the 'insitu' CBR value at formation from undrained shear strength data by applying a conversion factor of 23 (refer TRRL laboratory report LR889). Thus, adopting pessimistic undrained shear strength of say 50kN/m^2 at formation level (based on insitu shear strength measurements) then an equivalent CBR value can be obtained i.e.

Insitu CBR = undrained shear strength 50 / 23 = 2.1%

7.15.4.3 The 'insitu' CBR derived above, is susceptible to change dependent upon weather conditions during construction. We recommend the insitu CBR of 2.1% derived from shear strength data be utilised for design purposes and reassessed during construction. It should be noted that the thickness of the pavement foundation also relates to the amount and loading from construction traffic, which is discussed in detail in the Transport and Road Research Laboratory (TRRL) Report LR1132 '*Structural design of Bituminous Roads'.*

7.15.4.4 Made Ground deposits to some extent in Zones 2 and 4, comprise of landfill type material which will exhibit a degree of variation in compactness. Such material also contains elements of anthropogenic material which is likely to be susceptible to decomposition. Inundation settlement and possibly collapse settlement of voids could result in differential settlement to manifest across the pavement surface. It is difficult to calculate this accurately however to limit the amount of settlement across pavements in this area of the site, a number of options are available:

1. Either; once formation levels have been established the formation can be trimmed and rolled following current requirements of the Highways Agency Specification for Highways Works (clause 616) (refer www.dft.gov.uk/ha/standards/mchw/vol1). Such a process will identify any soft/loose areas, which we recommend be either excavated out and backfilled with a suitable well compacted material similar to those exposed in the sides of the resulting excavation, or large cobbles of a good quality stone rolled into the formation to stabilise the 'soft/loose' area. If excavated material is proposed to be re-used then any boulders and potentially degradable material should be removed prior to compaction.

2. **Or,** to further limit the degree of potential differential settlement, the initial 1m of soils below formation level could be excavated out, sorted and compacted in accordance with the Specification for Highways Works described above. This would not mitigate against settlement induced from decomposing of any fill material at depth.

3. **Or,** increasing and homogenising the density of the Made Ground/natural soils through ground improvement techniques such as vibrotreatment or permeation grouting/lime stabilisation. These are notably expensive and would require specialist input at the feasibility stage.

4. **And**, a geogrid could be incorporated within the design. Such a solution would not mitigate the potential for differential settlement but would limit the impact of such settlement at surface.

7.15.4.5 Consideration will need to be given to the possibility of proposed roads spanning across Made Ground and naturally deposited soils within Zone 4 and the likelihood that differential settlement will occur. This could be minimised by adopting some of the strategies outlined in paragraph 7.15.4.4 above.

7.15.5 Zone 3 (central part of the site)

7.15.5.1 Similarly with Zones 2 and 4, it is anticipated that excavations to formation level will encounter a mixture of both granular and cohesive soils within Zone 3.

7.15.5.2 Equilibrium CBR (California Bearing Ratio) values (with reference to Transport and Road Research Laboratory (TRRL) Report LR1132 '*Structural design of Bituminous Roads')* are derived from knowledge of soil classification data (plasticity index for soils exhibiting cohesion (clay type) and particle size distribution for granular soils), the location of the water table pavement thickness, and weather conditions at the time of construction. Assuming an average plasticity index of say 30 for cohesive soils (which will provide more conservative values), a low water table, a 'thin' pavement the following equilibrium CBR values are derived for varying construction conditions.

Equilibrium CBR values for differing construction conditions		
Poor	**Average**	**Good**
CBR = 3%	CBR = 4%	CBR = 4%

Table 7.15.5

We recommend these CBR values be utilised for design purposes and reassessed immediately prior to construction.

7.15.5.3 Again, it is possible to derive the 'insitu' CBR value at formation from undrained shear strength data by applying a conversion factor of 23 (refer TRRL laboratory report LR889). Thus, adopting pessimistic undrained shear strength of say 50kN/m^2 at formation level (based on insitu shear strength measurements) then an equivalent CBR value can be obtained i.e.

Insitu CBR = undrained shear strength 50 / 23 = 2.1%

7.15.5.4 The 'insitu' CBR derived above, is susceptible to change dependent upon weather conditions during construction. We recommend the insitu CBR of 2.1% derived from shear strength data be utilised for design purposes and reassessed during construction. It should be noted that the thickness of the pavement foundation also relates to the amount and loading from construction traffic, which is discussed in detail in the Transport and Road Research Laboratory (TRRL) Report LR1132 '*Structural design of Bituminous Roads'.*

7.15.5.5 Once formation levels have been established it is recommended that the formation be trimmed and rolled following current requirements of the Highways Agency Specification for Highways Works (clause 616) (refer www.dft.gov.uk/ha/standards/mchw/vol1). Such a process will identify any soft/loose areas, which we recommend be either excavated out and backfilled with a suitable well compacted material similar to those exposed in the sides of the resulting excavation, or large cobbles of a good quality stone rolled into the formation to stabilise the 'soft/loose' area.

7.15.6 Subgrade frost susceptibility

7.15.6.1 Near surface soils across the site are considered frost susceptible and this may override the CBR criteria for pavement foundation design purposes.

7.15.7 Moisture susceptibility

7.15.7.1 It is possible that due to the nature of near surface soils across the site, they could be moisture susceptible with small increases in moisture content giving rise to a rapid loss of support to construction plant. We therefore recommend, as soon as formation is trimmed and rolled, that sub-base is laid in order to avoid deterioration of the subgrade in wet or frosty conditions.

7.16 Reuse of excavated soils from the site

7.16.1 Generally naturally deposited soils excavated from the site could be reused as bulk filling, if reused at their natural moisture content. We recommend soils be classified and compacted in accordance with the current Highways Agency '*Specification for Highway Works'* (600 series) – table 6/1 (refer www.dft.gov.uk/ha/standards/mchw/vol1).

7.16.2 As described in preceding paragraphs, a significant cut and fill exercise is proposed across the site. We recommend that prior to works commencing, soils which are proposed for fill are tested to determine their suitability for reuse. Soiltechnics would be happy to undertake this upon further instruction.

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8 Chemical contamination

8.1 Contaminated land, regulation and liabilities

8.1.1 Statute

8.1.1.1 Part IIA of the Environment Protection Act 1990 became statute in April 2000. The principal feature of this legislation is that the hazards associated with contaminated land should be evaluated in the context of a site-specific risk based framework. More specifically contaminated land is defined as:

"any land which appears to the local authority in whose area it is situated to be in such a condition, by reasons of substances in, on or under the land, that:

a) Significant harm is being caused or there is a significant possibility of such harm being caused; or
b) Pollution of controlled waters is being or is likely to be caused".

8.1.1.2 Central to the investigation of contaminated land and the assessment of risks posed by this land is that:

i) There must be contaminants(s) at concentrations capable of causing health effects (*Sources).*
ii) There must be a human or environmental receptor present, or one which makes use of the site periodically *(Receptor)*; and
iii) There must be an exposure pathway by which the receptor comes into contact with the environmental contaminant *(Pathway).*

8.1.1.3 In most cases the Act is regulated by Borough or District Councils and their role is as follows:

i) Inspect their area to identify contaminated land
ii) Establish responsibilities for remediation of the land
iii) See that appropriate remediation takes place through agreement with those responsible, or if not possible:
- by serving a remediation notice, or
- in certain cases carrying out the works themselves, or
- in certain cases by other powers

iv) keep a public register detailing the regulatory action which they have taken

8.1.1.4 For "special" sites the Environment Agency will take over from the Council as regulator. Special sites typically include:-

- Contaminated land which affects controlled water and their quality
- Oil refineries
- Nuclear sites
- Waste management sites

8.1.2 Liabilities under the Act

8.1.2.1 Liability for remediation of contaminated land would be assigned to persons, organisations or businesses if they caused, or knowingly permitted contamination, or if they own or occupy contaminated land in a case where no polluter can be found.

8.1.3 Relevance to predevelopment conditions

8.1.3.1 For current use, Part IIA of the Environmental Protection Act 1990 provides the regulatory regime. The presence of harmful chemicals could provide a 'source' in a 'pollutant linkage' allowing the regulator (local authority or Environment Agency) to determine if there is a significant possibility of harm being caused to humans, buildings or the environment. Under such circumstances the regulator would determine the land as 'contaminated' under the provision of the Act requiring the remediation process to be implemented.

8.1.4 Relevance to planned development

8.1.4.1 The developer is responsible for determining whether land is suitable for a particular development or can be made so by remedial action. In particular, the developer should carry out an adequate investigation to inform a risk assessment to determine:

a) Whether the land in question is already affected by contamination through source – pathway – receptor pollutant linkages and how those linkages are represented in a conceptual model
b) Whether the development proposed will create new linkages e.g. new pathways by which existing contaminants might reach existing or proposed receptors and whether it will introduce new vulnerable receptors, and

c) What action is needed to break those linkages and avoid new ones, deal with any unacceptable risks and enable safe development and future occupancy of the site and neighbouring land?

8.1.4.2 Building control bodies enforce compliance with the Building Regulations. Practical guidance is provided in Approved documents, one of which is Part C, '*Site preparation and resistance to contaminants and moisture'* which seeks to protect the health, safety and welfare of people in and around buildings, and includes requirements for protection against harm from chemical contaminants.

8.1.5 Pollution of controlled waters

8.1.5.1 Part IIA of the Environment Protection Act 1990, defines pollution of controlled waters as

'The entry into controlled waters of any poisonous, noxious or polluting matter or any solid waste matter'

8.1.5.2 Paragraphs A36 and A39 of statutory guidance (DETR 2000) further define the basis on which land may be determined to be contaminated land on the basis of pollution of controlled waters.

'Before determining that pollution of controlled waters is being, or likely to be, caused, the Local Authority should be satisfied that a substance is continuing to enter controlled waters, or is likely to enter controlled waters. For this purpose, the local authority should regard something as being likely when they judge it more likely than not to occur'

'Land should not be designated as contaminated land where:

a) A substance is already present in controlled waters:
b) Entry into controlled waters of that substance from the land has ceased, and
c) It is not likely that further entry will take place.

Substances should be regarded as having entered controlled waters where:

a) They are dissolved or suspended in those waters; or
b) If they are immiscible with water, they have direct contact with those waters, or beneath the surface of the waters'

8.1.5.3 Controlled waters are defined in statute to be:

'territorial waters which extend seawards for 3 miles, coastal waters, inland freshwaters, that is to say, the waters in any relevant lake or pond or of so much of any relevant river or watercourse as is above the freshwater limit, and groundwaters, that is to say, any waters contained in underground strata.'

8.1.6 Further information

8.1.6.1 The above provides a brief outline as regards current statute and planning controls. Further information can be obtained from the Department for the Environment, Food and Rural Affairs (DEFRA) and their Web site www.defra.gov.uk.

8.2 Objectives and procedures

8.2.1 Objectives

8.2.1.1 This report section discusses investigations carried out with respect to chemical contamination issues relating to the site. As stated in Section 2.4.2, the investigation process followed the principles of BS10175: 2011 *'Investigation of potentially contaminated sites – Code of Practice',* with the investigation combining a desk study (preliminary investigation) together with the exploratory and main investigations (refer BS10175: 2011 for an explanation).

8.2.1.2 This section of the report produces *'Conceptual models'* based on investigatory data obtained to date. The conceptual model is constructed by identification of *contaminants* and establishment of feasible *pathways* and *receptors.* The conceptual model allows a *risk assessment* to be derived. Depending upon the outcome of the risk assessment it may be necessary to carry out remediation and/or further investigations with a view to eliminating, reducing or refining the risk of harm being caused to identified receptors. If appropriate, our report will provide recommendations in this respect.

8.2.1.3 We must consider the current pre-development condition, establishing risks which may require action to render the site safe to all relevant (current) receptors meeting the requirements of current legislation (Part IIA of the Environmental Protection Act 1990).

8.2.1.4 Definition of terms used in the preceding paragraph and subsequent parts of this section of the report are presented in Appendix B.

8.2.2 Procedure to assess risks of chemical contamination

8.2.2.1 For the purposes of presenting this section of this report, we have adopted the following sequence in assessing risks associated with chemical contamination.

Table outlining sequence to assess risk associated with chemical contamination		
Conceptual model element	**Contributory information**	**Outcome**
Receptor	Development categorisation	Identification of receptors at risk of being harmed Method of analysing test data Criteria for risk assessment modelling
Pathways	Geology and ground conditions Development proposals	Identification of critical pathways from source to receptor
Source	Previous site history Desk study information Site reconnaissance Fieldwork observations	Testing regime Identification of a chemical source Analysis of test data and other evidence

Table 8.2.2

8.2.2.2 We have adopted, in general, the procedures described in CIRIA C552 *'Contaminated land risk assessment - a guide to good practice'* in deriving a risk assessment. Initially we have carried out a 'phase 1 assessment' based on desk study information and site reconnaissance, to produce an initial conceptual model and thus a preliminary risk assessment. This model / assessment is then used to target fieldwork activities and laboratory testing, with the results of this part of the investigation used to allow a phase 2 assessment to be produced by updating the conceptual model and refining the risk assessment.

8.3 Development characterisation and identified receptors

8.3.1 Site characterisation

8.3.1.1 As outlined in Section 2, the client has opted to exclude development of the former landfill area of the site, referred to as Zone 1. As a consequence, plot layouts and proposed reprofiling of the site have been amended to optimise more developable areas of the site (Zones 2-4). Following receipt of updated layout plans, we have refined the below assessment based on development not being undertaken within Zone 1. Should this change, then this assessment should be revisited.

8.3.1.2 The nature of the site has a significant influence on the likely exposure pathways between potentially contaminated soils and potential receptors. The following table summarises elements which characterise the site based on site observations and desk study information.

Summary of site characteristics		
Element	**Source / criteria**	**Characteristic**
Current land use	Observations	Publicly accessible land, playing fields with children's play area, agricultural land and part of a golf course.
Future land use	Advice	Residential development which includes domestic gardens, and access roads
Site history	Desk study	Agricultural land (zones 3 and 4) railway land (zone 1 and 2) including an engine shed, coal hopper, recorded and unrecorded refuse tips (zone 1 and 2), infilled pond (zone 4).
Geology	Desk study	Less than 5m thickness of Alluvium (confined to area of brook), with Bowland Shale Formation to western and central parts of site (>20m thick), Eyam Limestone Formation to central and eastern parts of the site (<20m thick) and Bee Low Limestone Formation to east (>70m).
	Site investigation	Substantial Made Ground located within Zones 1 and 2 (some natural Bowland Shale Formation observed at depth in latter area), with Topsoil over weathered Eyam Limestone and Bowland Shale Formation to Zone 3, and Made Ground consistent with Zones 1 & 2 located in Zone 4 with some weathered Bee Low Limestone Formation (reworked locally).
Ground water	Aquifer potential	Principal aquifers within Eyam and Bee Low Limestone Formations. Secondary A Aquifer within Bowland shale Formation.
	Abstractions	4 active groundwater abstraction points within 2000m. Closest 672m to the southwest.
	Source protection zone	Site not within a source protection zone
Surface waters	Location	Nuns Brook present onsite flowing north-south between Zones 1/2 and 3. Culverted across the northern part.
	Abstractions	5 active surface water abstraction points within 2000m. Closest 569m to the southwest.

Table 8.3.1

8.3.2 Identified receptors

8.3.2.1 The principal receptors subject to harm caused by any contamination of the proposed development site are as follows.

Principle Receptor	Detail
Humans	Users of the current site
	End user of the developed site
	Construction operatives and other site investigators
Vegetation	Plants and trees, both before and after development
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)
	Ground waters (used for abstraction or feeding rivers / streams etc)
Building materials	Materials in contact with the ground

Table 8.3.2

This section of the report assesses those receptors listed above. Section 10 provides a risk assessment in relation to building materials.

8.3.3 Human receptors

8.3.3.1 The Contaminated Land Exposure Assessment (CLEA) model can be used to derive guideline values, against which land quality data can be compared to allow an assessment of the likely impacts of soil contamination on humans. The parameters used within the model can be chosen to allow guideline values to be derived for a variety of land uses and exposure pathways. For example, a construction worker is likely to be exposed in different ways and for different durations than an adult in a residential setting.

8.3.3.2 As the current site is largely accessible to the general public the critical site user (receptor) is considered to be a child under the age of 6 years. Following completion of the residential development in Zones 2 to 4, the critical site user (receptor) is again considered to be a child under the age of 6 years. This criterion has been used in the conceptual model for the current and future site use. Our assessment also considers construction operatives as adult receptors.

8.3.4 Vegetation receptors

8.3.4.1 Soil contaminants can have an adverse effect on plants if they are present at sufficient concentrations. The effects of phytotoxic contaminants include growth inhibition, interference with natural processes within the plant and nutrient deficiencies.

8.3.4.2 Mature and semi-mature trees are present on site and will remain so following development to some extent, with the addition of garden areas. Therefore, vegetation is considered as a viable receptor in both current and future land use.

8.3.5 Water receptors

8.3.5.1 The site lies in an area designated as a principal aquifer contained in the Eyam Limestone Formation and Bee Low Limestone Formation, as well as a secondary A aquifer within the Bowland Shale Formation. The channel of Nun Brook is present onsite, flowing north-south between Zones 1/2 and 3, culverted in the northern part of site. Based on such, both surface water and groundwater are considered to be viable receptors.

8.3.5 Summary of identified receptors

8.3.5.1 Based on the above assessments, the following table summarises identified and critical receptors.

Table summarising identified (viable) receptors				
Principle Receptor	**Detail**	**Viable and critical receptors**		
		Viability and justification		**Critical receptor**
Humans	Users of the current site (Zones 2-4 only)	Yes	Site accessible to public including children	Child
	End user of the developed site (Zones 2-4 only)		Residential development	
	Construction operatives and other site investigators			Adult
Vegetation	Current site		Trees on site	Vegetation
	Developed site		Trees to remain	
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)		Nun Brook onsite	Surface waters
	Ground waters (used for abstraction or feeding rivers / streams etc)		Site over principal aquifers	Groundwater
Building materials	Materials in contact with the ground		Assessed in report section 10	Building materials
Table 8.3.5				

8.4 Identification of pathways

8.4.1 Pathways to human receptors

8.4.1.1 Guidance published by the Environment Agency in Science Report SC050021/SR3 *'Updated technical background to the CLEA model'* provides a detailed assessment of pathways and assessment and human exposure rates to source contaminants. In summary, there are three principal pathway groups for a human receptor:

Table summarising likely pathways	
Principal pathways	**Detail**
Ingestion through the mouth	Ingestion of air-borne dusts
	Ingestion of soil
	Ingestion of soil attached to vegetables
	Ingestion of home grown vegetables
Inhalation through the nose and mouth.	Inhalation of air-borne dusts
	Inhalation of vapours
Absorption through the skin.	Dermal contact with dust
	Dermal contact with soil
Table 8.4	

8.4.1.2 The site is currently used as agricultural/grazing land and publicly accessible areas. All the above pathways are present on site with the exception those related to consumption of vegetables for current users. Such pathways will also be considered for construction operatives.

8.4.1.3 Zone 2, 3 and 4 are to be developed for residential end use with gardens. Therefore, all of the above pathways will be viable for end users of the site.

8.4.1.4 A summary of our pathway assessment is presented in Section 8.4.4.

8.4.2 Pathways to vegetation

8.4.2.1 Guidance published by the Environment Agency in Science Report SC050021/SR (Evaluation of models for predicting plant uptake of chemicals from soil) provides a detailed assessment of plant uptake pathways. In summary, plants are exposed to contaminants in soils by the following pathways:

- Passive and active uptake by roots.
- Gaseous and particulate deposition to above ground shoots.
- Direct contact between soils and plant tissue.

8.4.2.2 All of the above routes of exposure are considered to be present for vegetation.

8.4.3 Pathways to controlled waters

8.4.3.1 A number of pathways exist for the transport of soil contamination to controlled waters. A summary of these pathways is presented below:

- Percolation of water through contaminated soils.
- Near-surface water run-off through contaminated soils.
- Saturation of contaminated soils by flood waters.

8.4.3.2 All of the above pathways are considered to be present to controlled waters, however saturation of contaminated soils by flood waters is likely to be extremely limited and confined to the channel of Nun Brook to the far south of the site. Therefore, we have assumed such a pathway would have a negligible impact on the site at present.

8.4.4 Summary of identified likely pathways

8.4.4.1 Based on the above assessments, the following table summarises likely pathways of potential chemical contaminants at the site to identified receptors.

Table of likely pathways		
Receptor group	**Critical receptor**	**Pathway**
Current and proposed site users	Child	Ingestion air-borne dusts
		Ingestion of soil
		Inhalation air-borne dusts
		Inhalation of vapours
		Dermal contact with dust
		Dermal contact with soil
Construction Operatives	Adult	Ingestion air-borne dusts
		Ingestion of soil.
		Inhalation air-borne dusts
		Inhalation of vapours
		Dermal contact with dust
		Dermal contact with soil
Proposed site users	Child	Ingestion of home grown vegetables
		Ingestion of soil attached to vegetables
Vegetation		Root uptake, deposition to shoots and foliage contact.
Controlled waters	Groundwater	Percolation of water through contaminated soils
	Surface water	Near-surface water run-off through contaminated soils

Table 8.4.4

8.5 Assessment of sources of chemical contamination

8.5.1 Introduction

8.5.1.1 Initially, potential sources of contamination are assessed using the following elements of the investigation process.

- History of the site
- Desk study information
- Site reconnaissance
- Geology
- Fieldwork

These elements will dictate a relevant soil/water testing regime to quantify possible risks of any identified contaminative sources which may harm identified receptors.

8.5.2 Source assessment – History of the site

8.5.2.1 The history of the site and its immediate surroundings based on published Ordnance Survey maps is described in Section 3.

8.5.2.2 Based on published historical maps, the area of Zone 2 to the west/southwest was occupied by railway sidings with associated engine shed, turntable, coal hopper and localised tanks between 1898 and 1974. A refuse tip was present in the area of Zone 1 to the northwest between 1966 and 1989. Additionally, a mere (large pond) was present in Zone 4 to the east of the site between 1879 and 1967.

8.5.2.3 The former railway land site usage associated to the railway is included in *'Industry profiles' Railway land;* published by the department of the Environment, which provides an indication of the type of chemical contaminants likely to be used by the industry. In addition, the landfill area to the northwest is included in *'Industry profiles' Waste recycling, treatment and disposal sites.* Clearly, the possibility of potential soil contamination from this former land use would be dependent upon the management of the potential contaminants within this former industry. Contaminants of concern are listed in table 8.5.2.6 below. At this stage we have assumed there is a risk of each of the potential contaminants impacting soils at the site, and thus there is a potential (and thus a risk) of this chemical source causing harm to site receptors.

8.5.2.4 Some areas of the site formed agricultural land and allotments historically, and may have been utilised for growing crops and thus likely to have been subject to the use of pesticides/herbicides. It is considered unlikely that significant concentrations of such chemicals will have been utilised in recent years in accordance with DEFRA standards for growing crops. Considering the components of pesticide, organics are unlikely to persist in the environment however metals are present in pesticides which can persist in the environment and thus could remain present in soils. Such metals include arsenic, copper, chromium, lead, zinc and vanadium. These metals form part of our suite of laboratory tests for which concentrations are measured in soil samples.

8.5.2.5 A small number of historical surrounding land uses (other than the landfill site to Zone 1) may also have the potential to generate sources of contamination which could impact the subject site. These would include similar land uses to those identified onsite already, in addition to works and depots. Such contaminants are similar to those already identified, thus, to save repetition, we have not specifically included as a source.

8.5.2.6 Clearly, the possibility of potential soil contamination from these land uses would be dependent upon the management of the potential contaminants within the business. An assessment of the likelihood of this land use impacting the site is summarised in the table below: -

Table summarising results of source assessment

Historical/ current activity	Contaminant(s)	Source assessment	Probability of source	Testing required?
On site				
Railway land	Metals, PAHs, TPHs, acids and alkalis, asbestos	Railway land recorded in area of Zone 2.	Likely	Yes
Infilled pond	Metals, Organics, PAH, TPH, asbestos	Pond infilled to east in Zone 4.	Likely	Yes
Agricultural land and allotments	Metals	Particularly area of Zone 3 and 4.	Likely	Yes
Adjacent sites				
Hogshaw Landfill	Metals, Organics, PAH, TPH, asbestos	Former landfill to northwest in Zone 1.	Likely	Yes

Table reference 8.5.2.6

8.5.3 Source assessment – Desk study information

8.5.3.1 Envirocheck presents a detailed database of environmental information in relation to the site including;

- Pollution incidents
- Landfill sites
- Trading activities

8.5.3.2 Based on the Envirocheck data (refer Appendix M) area of land forming Zone 1 has been subject to landfilling activities. Records indicate that it was licenced for receipt of inert, industrial and commercial waste. Furthermore, the Local Authority planning portal of High Peak Borough Council, records a refuse tip in the area of the existing recreation ground to the southwest of the site (Zone 2). The extent of the tip is not recorded. In addition to this a number of quarries were noted on historical mapping which may pose a source of contamination if infilled. Envirocheck also record an area of infilled land to the east (Zone 4), associated with the backfilling of Russia Mere. The above are likely to represent sources of contamination worthy of further consideration.

8.5.3.3 The nearest incident is recorded 189m to the south of site, associated with release of oils/diesel into Hogshaw Brook, dated in February 1998. The closest significant incident is recorded 316m to the south, associated with release of unknown organic wastes into Hogshaw Brook, dated April 1997. Given these incidents are located downstream from site, they are not likely to represent sources of contamination worthy of further consideration.

8.5.3.4 Nine active trade directory entries are recorded within 500m of the site, the closest of which is recorded 13m to the northeast, classified as Garage Services at Nunsfield Farm (Buxton 4x4). The closest inactive entry is located 5m to the northeast, associated with an Agricultural Merchants at Nunsfield Farm. The garage use may provide a source of localised contamination which could affect the subject site and is worthy of further consideration.

8.5.4 Source assessment – Site reconnaissance

8.5.4.1 A full description of the site and observed adjacent land uses is provided in Section 3 of this report. A plan summarising observations made on site during our site reconnaissance visit is presented on Drawing 02.

8.5.4.2 Localised areas of fly tipping were observed in Zone 2, and garages were present in the central and southern parts of this area, which may pose a localised source of contamination, including solvents, metals, PAHs, TPHs and asbestos.

8.5.5 Source assessment – Geology

8.5.5.1 The geological map of the area indicates the topography local to the site is formed in deposits of Bowland Shale Formation, Eyam Limestone Formation and Bee Low Limestone Formation. Typically, and in our experience, such deposits do not exhibit any abnormal concentrations of naturally occurring chemical contaminants.

8.5.6 Source assessment - Fieldwork observations

8.5.6.1 During excavation of exploratory locations within western parts of the site (Zone 2), we observed significant quantities of anthropogenic material, generally consistent with localised landfilling activities, and associated with the former railway land. Specifically, these included, slag, ash and general commercial wastes (textiles, paper etc). Similar materials were encountered locally in the eastern part of site (Zone 4), likely associated with infilling of the Mere and localised earthworks adjacent to the graveyard.

8.5.6.2 It should be noted that localised investigations undertaken in the Zone 1 landfill area identified significant quantities of anthropogenic material, consistent with landfilling activities. Specifically, these included potential asbestos containing materials (ACMs), significant quantities of biodegradable matter and general commercial wastes (textiles, paper etc).

8.5.6.3 In addition, a hydrocarbon odour was observed in Made Ground soils encountered between depths of 1.9-3.4m in trial pit TP05 (Zone 1 landfill area).

8.5.6.4 We obtained samples of the potentially chemically impacted soils for subsequent laboratory testing.

8.5.7 Source assessment - summary

8.5.7.1 Based on the paragraphs above, we have identified the following potential sources of contamination:

Table summarising results of source assessment				
Source	**Origin of information**	**Possible contaminant**	**Probability of risk occurring**	**Likely extent of contamination**
On site				
Railway Land	Desk Study and site investigations	Metals, PAHs, TPHs, acids and alkalis, asbestos	Likely	Western part of site (Zone 2)
Infilled Pond				Eastern part of site (Zone 4)
Agricultural land and allotments		Metals		Particularly area of Zones 3 and 4
Fly tipping and garages	Site reconnaissance	Solvents, metals, PAHs, TPHs and asbestos	Possible	Central and south parts of site (Zone 2)
Localised landfill type materials and TPH contamination	Fieldworks	Metals, Organics, PAH, TPH, asbestos	Likely	Zones 2, 4 and local to TP05 (TPH)
Adjacent sites				
Garage services	Site reconnaissance	Metals, PAHs, TPH, asbestos	Possible	Eastern part of site (Zone 3 and 4)
Former quarries	Desk Study		Low Likelihood	Site wide
Hogshaw Landfill/ Hogshaw Tip	Desk Study and site investigations	Metals, Organics, PAH, TPH, asbestos	Possible	Western parts of Zone 3 and northern parts of Zone 2
Table reference 8.5.7				

8.6 Initial Conceptual Model

8.6.1 Based on our assessment of potential contaminative sources, identified receptors and viable pathways to receptors described in preceding paragraphs, we have produced an initial conceptual model in the form of a table which is presented in Appendix J.

8.6.2 Based on the conceptual model there are risks which exceed the low category which in our opinion are unacceptable and require either remedial action, or further investigation by laboratory testing of soil / water samples to refine the risk assessment.

8.7 Laboratory testing

8.7.1 Testing regime

8.7.1.1 Based on our source assessment (and our initial conceptual model) we have evidence to suggest that significant sources of specific contamination are potentially present onsite and on immediately adjacent sites. In order to carry out a quantitative, we have scheduled testing to measure the concentration of commonly occurring inorganic and organic contaminants, in addition to specific contaminants where necessary based on the locations of identified sources.

8.7.1.2 As outlined in paragraph 8.3.1.1, we have refined the following assessments based on development not being undertaken within Zone 1. We have presented the testing that was originally scheduled on soils taken from exploratory investigations within Zone 1 in the following table for completeness, however, such results have been omitted from subsequent interpretive analysis.

8.7.1.3 The following table summarises the chemical testing scheduled as well as a rationale for the testing: -

Table summarising scheduled testing

Exploratory point	Depth (m)	Strata/ medium	Targeted sampling?	Scheduled testing	Rationale
TP01	0.3	Gravel	N	Suite 1	General site coverage
TP02	0.3	Sand	N		
TP03	0.2	Topsoil	N		
TP04	0.2	Topsoil	N		
TP05*	0.8	Made Ground - Sand	Y		Historical landfill area
TP06	0.3	Topsoil	N		General site coverage
TP10	0.8	Made Ground - Sand	Y		Former railway land
TP11	0.3	Topsoil	N		General site coverage
DTS01*	0.5	Made Ground - Clay	Y		Historical landfill area
DTS01*	0.8	Made Ground - Clay	Y		
DTS02	0.3	Topsoil	N		General site coverage
DTS03	0.3	Topsoil	N		
DTS04*	0.5	Made Ground - Clay	Y		Historical landfill area
DTS06	0.3	Topsoil	N		General site coverage
DTS07	0.3	Topsoil	N		
DTS09	0.3	Topsoil	N		
DTS12	0.3	Topsoil	Y		Next to agricultural supplier yard
DTS15	0.3	Topsoil	N		General site coverage
DTS18	0.3	Topsoil	N		
DTS20	0.5	Made Ground - Sand	Y		Next to garage
DTS20	0.8	Made Ground - Sand	Y		
DTS23	0.8	Made Ground - Sand	Y		General site coverage
DTS28	0.8	Clay	N		
TP05*	0.8	Made Ground - Sand	N	Asbestos screening	General site coverage
TP07	0.5	Made Ground - Gravel	Y		Potential ACM contamination
TP09	0.5	Made Ground - Gravel	N		General site coverage
TP18*	0.8	Made Ground - Sand	Y		Potential ACM material
TP18*	1.2	Made Ground - Sand	Y		
TP18*	1.4	Made Ground - Sand	Y		
TP18*	1.6	Made Ground - Sand	Y		
DTS13	0.8	Made Ground - Sand	N		General site coverage
DTS16	0.8	Made Ground - Gravel	N		
DTS20	0.8	Made Ground – Sand	Y		Potential ACM contamination
DTS21	0.5	Made Ground - Sand	N		General site coverage
DTS22	1.2	Made Ground - Sand	N		
DTS26	0.8	Made Ground - Clay	N		
DTS28	0.8	Clay	N		
DTS29	1.2	Made Ground - Sand	N		
TP03	0.5	Gravel	N	Suite 8	General site coverage
TP16	0.5	Made Ground - Gravel	N		
TP18*	0.5	Made Ground - Sand	N		
TP20	0.5	Made Ground - Sand	N		
DTS02	0.5	Sand	N		
DTS07	0.8	Clay	N		
DTS19	0.5	Made Ground - Sand	N		

DTS19	1.2	Gravel	N		
DTS21	1.8	Made Ground - Clay	N		
DTS22	1.8	Clay	N		
TP05*	2.5	Made Ground - Sand	Y	Suite 2	Hydrocarbon odour noted
TP07	0.8	Made Ground - Gravel	Y		Garages with asbestos noted
TP05*	1.2	Made Ground – Sand	Y	Suite 17	Historical Landfill
TP05*	1.8	Made Ground – Sand	Y		
TP08	0.8	Made Ground – Sand	Y		Potentially infilled pond
TP08	1.2	Made Ground – Sand	Y		
TP09	0.8	Clay	N		General site coverage
TP20	1.2	Made Ground – Clay	Y		Next to garage
DTS04*	0.8	Made Ground – Gravel	Y		Historical landfill area
DTS09	0.5	Clay	N		Next to agricultural supplier yard
DTS16	0.8	Made Ground - Gravel	N		General site coverage
DTS20	1.2	Made Ground - Sand	Y		Landfill material encountered
DTS25	0.5	Made Ground - Sand	Y		
Nuns Brook Upstream1	Surface	Water	Y	Suite 17 – Water	Nuns Brook immediately upstream of site
Nuns Brook Downstream1	Surface	Water	Y		Nuns Brook immediately downstream of site
DTS19	3.2	Water	Y		Groundwater onsite

Table 8.7.1.2

Refer to Appendix B for testing suite descriptions

*Exploratory points located within former landfill area (Zone 1), excluded from subsequent interpretative analysis.

8.7.1.4 Obviously, additional testing (quantity and types) would allow a more accurate risk assessment to be made. The results of laboratory determination of the concentrations of chemical contaminants are presented in Appendix H.

8.7.2 Criteria for assessment of test data – Human receptors

8.7.2.1 Assessment of laboratory test data has been carried out with reference to current nationally recognised documents listed in the final page of Appendix B. Due to changes in guidance on contaminated land, items 6-8 and item 10 in the document listing above have been withdrawn. In the absence of alternative guidance however we have used these documents. Where new guidance is available, this has been followed in preference to superseded guidance.

8.7.2.2 The Land Quality Management (LQM) and the Chartered Institute of Environmental Health (CIEH) have derived Suitable for Use Levels (S4ULs) which are presented in *'The LQM/CIEH S4ULs for Human Health Risk Assessment'* (2015). S4ULs have been used as a screening tool to assess the risks posed to the health of humans from exposure to soil contamination in relation to appropriate land uses. Where published S4ULs are not available, we have adopted C4SLs (Category 4 Screening Levels) produced by DEFRA or SGVs (Soil Guideline Values) as appropriate. Where available, we have adopted the upper bound C4SL value. In the absence of any of these criteria we have adopted Soil Screening Values (SSV) derived by Soiltechnics and by Atkins (SSV^{ATK}). The CLEA model used to derive SSVs has been used with toxicology data presented by the EA, LQM/CIEH and Atkins (in that order of preference). SSVs produced by Atkins are presented on their $ATRISK^{SOIL}$ website.

8.7.2.3 S4ULs, C4SLs, SGVs, SSVs and SSV^{ATK}s represent 'intervention values'; indications to an assessor that soil concentrations above these levels might present an unacceptable risk to the health of site users. These guideline values have been produced using conceptual exposure models, which use assumptions and are applied to differing end uses of land. If the values are exceeded, it does not necessarily imply there is an actual risk to health and site-specific circumstances should be taken into account. Conversely, where a critical pathway or chemical form of the contaminant has not been evaluated, a risk may be present even if the adopted guideline value has not been exceeded.

8.7.2.4 For evaluation of test data in relation to polycyclic aromatic hydrocarbon (PAH), phenols and total petroleum hydrocarbon (TPH) contamination, we have compared measured concentrations with corresponding S4ULs. The S4UL fractions are dependent on the Soil Organic Matter (SOM) content of the soils. We have adopted the relevant guideline values based on SOM testing.

8.7.2.5 We have followed procedures outlined by the CIEH to compare measured concentrations of metals and PAH contaminants against guideline values. TPH contamination results are compared directly with the relevant guideline values. The guidance presents an approach to data analysis and includes the examination of data for potential outliers, assessment of the normality of the test data and the calculation of a 95% Upper Confidence Limit (UCL). The UCL provides an estimate of the population mean, based on test data, with a 95% confidence that the actual mean does not exceed this value. The UCL is compared to the guideline value for the site.

8.7.2.6 We have adopted a public open space (POS park) land use for current site users and a residential land use for proposed end users of the site.

8.7.3 Criteria for assessment of test data – Construction operatives

8.7.3.1 In the absence of guidelines we have adopted industrial/commercial guideline values for assessment of construction operatives.

8.7.4 Criteria for assessment of test data – Vegetation

8.7.4.1 Guidance published by Forest Research in "*BPG Note 5 - Best Practice Guidance for Land Regeneration*" suggests that a residential without plant uptake or industrial/commercial CLEA model should be adopted for this receptor. Specific guideline values are provided for copper and zinc at 130mg/kg and 300mg/kg respectively within BPG 5, however, this document has recently been withdrawn. As a practice we have adopted the industrial / commercial CLEA model for assessment of test data for vegetation, including those specific values outlined in BPG 5 until updated guidance is published.

8.7.4.2 It is difficult to quantify the phytotoxity of a contaminant as large variations exist between plant tolerances, soil effects and synergistic/antagonistic reactions between chemicals. Due to the complexities of the effects of soil contamination on different plant species, we recommend that the test results presented in this report are passed to a landscape architect for the selection of suitable planting.

8.7.5 Criteria for assessment of test data – Controlled waters

8.7.5.1 For interpretation of test data in relation to water receptors we have directly compared measured values with the Drinking Water Standards (DWS) as presented in *"The Water Framework Directive (Standards and Classification) Directions (England and Wales)* 2015*"*. Where DWS are not available we have adopted EQS values where applicable.

8.7.5.2 For assessment of TPH concentrations, we have adopted World Health Organisation (WHO) Drinking Water Guidelines as presented in CL:AIRE guidance *"Petroleum Hydrocarbons in Groundwater"*, 2017.

8.7.5.3 Following our receptor assessment (outlined in Section 8.3.5 above), given that Nun Brook flows through site, we have adopted EQS values in preference to UKDWS. It is acknowledged that the site is underlain by Principal Aquifers in the limestones, however given the relative position of the brook onsite, in comparison to groundwater abstractions (closest 672m southwest), we have considered the brook to be at greater risk of being adversely impacted by any contamination onsite.

8.7.6 Evaluation of test data – Human receptors

8.7.6.1 Tables summarising and analysing test data are presented in Appendix I. The following table summarises the outcome of the analyses. It should be noted that we have assessed measured concentrations in Topsoil separate to those measured in Made Ground deposits across the site, given their distinct compositional difference.

Table Summarising assessment of test data for Human receptors					
Analysis tables	**Receptor group**	**Critical receptor**	**CLEA model**	**Inorganic contaminants**	**Organic contaminants**
1, 2, 9, 10 and 15	Current site users	Child	Public open space (park)	Refer to Section 8.7.6.2 below	Refer to Section 8.7.6.2 below
3, 4, 11, 12 and 16	Future site users	Child	Residential with plant uptake	Refer to Section 8.7.6.3 below	Refer to Section 8.7.6.3 below
5, 6, 13, 14 and 17	Construction operatives	Adult	Industrial / commercial	Refer to Section 8.7.6.4 below	Refer to Section 8.7.6.4 below

Table 8.7.6.1

8.7.6.2 Current site users

8.7.6.2.1 With reference to tables 1, 2, 9, 10 and 15 in Appendix I, analysis of chemical test data with respect to critical (child) receptors for current site uses, indicates all measured concentrations of selected contaminants and 95th percentile upper confidence limits (UCL) are below relevant adopted guideline values, with the exception of lead and dibenzo(a,h)anthracene in two samples, and benzo(a)pyrene and benzo(b) fluoranthene in one sample, all measured in Made Ground deposits (total of 10 No. samples tested).

8.7.6.2.2 Lead was measured at concentrations of 2700mg/kg (DTS20 0.5m) and 7400mg/kg (DTS23 0.8m) exceeding the C4SL (u) of 1400mg/kg. The UCL of 4482.7mg/kg for lead also exceeds the guideline value. Dibenzo(a,h)anthracene was measured at concentrations of 3.4mg/kg and 4.8mg/kg, exceeding the S4UL of 1.3mg/kg. The UCL of 3.3mg/kg for dibenzo(a,h)anthracene also exceeds the guideline value. The elevated concentrations of benzo(a)pyrene and benzo(b)fluoranthene were measured at 15mg/kg and 18mg/kg, exceeding the respective S4ULs of 12mg/kg and 15mg/kg), both located within TP10 at 0.8m depth. Such contamination was present in Zones 2 and 4.

8.7.6.2.3 Analysis indicates that concentrations of contaminants measured in all Topsoil and naturally deposited soils (17 No. samples) fall below relevant guidelines for current users.

8.7.6.3 Future site users

8.7.6.3.1 With reference to tables 3, 4, 11, 12 and 16 in Appendix I, analysis of chemical test data with respect to critical (child) receptors for future site uses, indicates all measured concentrations of selected contaminants and 95 percentile upper confidence limits (UCL) are below relevant adopted guideline values, with the exception of arsenic, beryllium, lead and nickel in a small number of Topsoil/natural soil samples, and arsenic, beryllium, lead, mercury, benzo(a) anthracene, benzo(a)pyrene, benzo(b)fluoranthene and dibenzo(a)anthracene in a large number of Made Ground samples.

8.7.6.3.2 Four elevated concentrations of arsenic have been measured in Topsoil/natural soils, recorded between 49mg/kg and 65mg/kg (S4UL of 37mg/kg), with five elevated concentrations of beryllium recorded ranging between 1.8mg/kg to 2.5mg/kg (S4UL of 1.7mg/kg), three elevated concentrations of lead ranging between 250mg/kg and 320mg/kg (C4SL (u) of 210mg/kg) and a single elevated concentration of nickel measured at 200mg/kg (S4UL of 180mg/kg). Such contamination was locally present in Topsoil/natural soils within Zones 3 and 4.

8.7.6.3.3 Within Made Ground samples, the following exceedances have been identified: -

- Arsenic within 9 of 10 samples, with exceedances measured at concentrations ranging between 47mg/kg and 160mg/kg. The mean value of 84.3mg/kg and UCL of 109.6mg/kg also exceed the guideline value (S4UL of 37mg/kg). Samples are located within Zones 2 and 4.
- Beryllium within 8 of 10 samples, with exceedances measured at concentrations ranging between 3.6mg/kg and 9.6mg/kg. The mean value of 5.3mg/kg and UCL of 7.2mg/kg also exceed the guideline value (S4UL of 1.4mg/kg). Samples are located within Zones 2 and 4.
- Lead within 7 of 10 samples, with exceedances measured at concentrations ranging between 420mg/kg and 7400mg/kg. The mean value of 1357.4mg/kg and UCL of 4482.7mg/kg also exceed the guideline value (C4SL(u) of 210mg/kg). Samples are located within Zones 2 and 4.

- Mercury within 1 of 10 samples, with an exceedance measured at a concentration of 1.6mg/kg (DTS23 0.8m) within Zone 2, exceeding the S4UL of 1.2mg/kg. The mean value of 1.3mg/kg also exceeds the guideline value.
- Benzo(a)anthracene within 1 of 10 samples, with an exceedance measured at a concentration of 12mg/kg, (TP10 0.8m) within Zone 2, exceeding the S4UL of 11mg/kg.
- Benzo(a)pyrene within 3 of 10 samples, with exceedances measured at concentrations ranging between 3.1mg/kg and 15mg/kg, exceeding the S4UL of 2.7mg/kg. The UCL of 9.0mg/kg also exceeds the guideline value. Samples are located within Zones 2 and 4.
- Benzo(b)fluoranthene within 3 of 10 samples, with exceedances measured at concentrations ranging between 3.6mg/kg and 18mg/kg, exceeding the S4UL of 3.3mg/kg. The UCL of 11.0mg/kg also exceeds the guideline value. Samples are located within Zones 2 and 4.
- Dibenzo(a,h)anthracene within 3 of 10 samples, with exceedances measured at concentrations ranging between 1.1mg/kg and 4.8mg/kg, exceeding the S4UL of 0.28mg/kg. The mean value of 1.0mg/kg and UCL of 3.3mg/kg also exceed the guideline value. Samples are located within Zones 2 and 4.

8.7.6.4 Construction operatives

8.7.6.4.1 With reference to tables 5, 6, 13, 14 and 17 in Appendix I, analysis of chemical test data with respect to construction operatives (adult receptors), indicates all measured concentrations of selected contaminants and 95 percentile upper confidence limits (UCL) are below relevant adopted guideline values, with the exception of one concentration of both lead and dibenzo(a,h)anthracene in Made Ground deposits.

8.7.6.4.2 Elevated lead was measured at a concentration of 7400mg/kg (DTS23 0.8m) exceeding the C4SL (u) of 6000mg/kg, with dibenzo(a)anthracene measured at a concentration 4.8mg/kg (TP08 1.2m), exceeding the S4UL of 3.6mg/kg, Such contamination was present in Zone 4.

8.7.6.4.3 Analysis indicates that concentrations of contaminants measured in all Topsoil and naturally deposited soils (17 No. samples) fall below relevant guidelines for construction operatives.

8.7.6.5 Asbestos

8.7.6.5.1 Asbestos screening was carried out in 9 samples of Made Ground and 1 sample of natural soil. Analysis indicates that asbestos is present in 3 of the 14 samples of Made Ground tested (DTS13, DTS20 and DTS22 within Zones 2 and 4), described as chrysotile fibres/clumps. Where analysed, total asbestos (%) content was recorded below 0.002% w/w with the exception for DTS13 at 0.8m depth, which recorded asbestos at 53% w/w.

8.7.6.6 VOCS & SVOCs

8.7.6.6.1 In addition to the above, with the exception of PAHs, BTEX and MTBE, a number of other Volatile and Semi Volatile Organic Compounds (VOC & SVOCs) were scheduled for testing. The majority of compounds tested for indicated measured concentrations below detectable limits, however, concentrations were measured for a select number, as follows: -

Table Summarising VOC/SVOC contamination for Human receptors

Location	Depth (m)	Compound	Concentration	Guideline*
DTS25	0.5	2-Methylnaphthalene	0.17mg/kg	N/A
DTS16	0.8	Carbazole	0.087mg/kg	N/A
		Butylbenzyl Phthalate	0.074mg/kg	N/A
TP08	1.2	2-Methylnaphthalene	0.43mg/kg	N/A
		Dibenzofuran	0.32mg/kg	N/A
		Carbazole	0.56mg/kg	N/A
		Butylbenzyl Phthalate	0.094mg/kg	N/A
		Bis(2-Ethylhexyl)Phthalate	0.31mg/kg	N/A
		Di-N-Octyl Phthalate	0.067mg/kg	N/A
		4-Nitrophenol	0.31mg/kg	N/A

Table 8.7.6.6

*Guideline values presented in from Soil Generic Assessment Criteria for Human Health Risk Assessment, January 2010, produced by CL:AIRE (including EIC and AGS).

8.7.6.6.2 Based on the above, guideline values are not currently available for the measured concentrations of VOCs/SVOCs detected. Thus, we have provided further details on these in the following paragraphs. It is noted that the CL:AIRE document as outlined in Table 8.7.6.6 above indicates that the pathway exposure contributions SVOCs are predominantly associated with inhalation of vapours and background inhalation.

8.7.6.6.3 A large number of the VOCs/SVOCs for which guidelines are not currently available are commonly used in insecticides, fungicides, herbicides, pesticides, in addition to dyes, heat transfer agents, plasticisers, lubricants and fuel additives.

8.7.6.6.4 The contaminants identified above have all been measured in Made Ground deposits at the site, largely consistent with the landfill type Made Ground deposits encountered in Zone 2 and partly Zone 4. It is therefore, most likely that such contamination is indicative of the source location where the materials were imported from prior to landfilling or re-profiling works which the site has been subject to.

8.7.6.6.5 Based on the above, such contaminants are unlikely to pose a risk to human health via pathways associated with dermal contact or ingestion. The greatest risk will be associated with vapour pathways and background inhalation, as outlined above in paragraph 8.7.6.6.2. Given the relatively insignificant concentrations measured, however, and when taken in context with the GACs that are currently available for VOC/SVOC for varying land uses, it is considered unlikely that such contaminants would pose a risk to human health via vapour pathways.

8.7.7 Evaluation of test data – Vegetation

8.7.7.1 With reference to tables 7, 8, 13, 14 and 17 in Appendix I, analysis of chemical test data with respect to vegetation indicates all measured concentrations of selected contaminants and 95 percentile upper confidence limits (UCL) are below relevant adopted guideline values, with the exception of copper, and zinc in a small number of Topsoil/natural soil samples, and copper, lead, zinc and dibenzo(a,h)anthracene in a number of Made Ground samples.

8.7.7.2 Two elevated concentrations of zinc have been measured in Topsoil/natural soils, recorded at 350mg/kg and 370mg/kg (BPG 5 value of 300mg/kg), with copper elevated in one sample, measured at a concentration of 140g/kg (BPG 5 of 130mg/kg). Such contamination was locally present in Topsoil/natural soils within Zone 3.

8.7.7.3 Within Made Ground samples, the following exceedances have been identified: -

- Copper within 9 of 10 samples, with exceedances measured at concentrations ranging between 140mg/kg and 700mg/kg. The mean value of 388.4mg/kg and UCL of 754.3mg/kg also exceed the guideline value (BPG 5 value of 130mg/kg). Samples are located within Zones 2 and 4.
- Zinc within 4 of 10 samples, with exceedances measured at concentrations ranging between 440mg/kg and 1000mg/kg. The mean value of 357.1mg/kg and UCL of 756.8mg/kg also exceed the guideline value (BPG 5 value of 300mg/kg). Samples are located within Zones 2 and 4.
- Lead within one sample (DTS23 0.8m), measured at a concentration of 7400mg/kg and exceeding the S4UL of 6000mg/kg. Sample located within Zone 2.
- Dibenzo(a,h)anthracene within one sample (TP08 1.2m), measured at a concentration of 4.8mg/kg and exceeding the S4UL of 3.6mg/kg. Sample located within Zone 4.

8.7.8 Evaluation of test data – Controlled waters

8.7.8.1 Inorganic contaminants

8.7.8.1.1 With reference to Table 18 in Appendix I, none of the measured concentrations of inorganic soluble and leachable contaminants exceed the relevant guidelines with the exception for soluble copper (EQS of 1µg/l) within a groundwater sample from DTS19 at 3.2m, measured at 1.2µg/l, and a surface water sample from Nun Brook downstream of the site, measured at 1.1µg/l. In addition, a leachable concentration of copper was measured in natural soils from DTS106 0.8m, measured at 10µg/l.

8.7.8.2 Organic contaminants (polycyclic aromatic hydrocarbons)

8.7.8.2.1 With reference to Table 18 in Appendix I, none of the measured concentrations of inorganic soluble and leachable contaminants exceed the relevant available guidelines.

8.7.8.3 Organic contaminants (total petroleum hydrocarbons)

8.7.8.3.1 The measured values of soluble TPH contaminants fall below the relevant guideline values, with many being below the limit of detection.

8.8 Updated conceptual model

8.8.2 Current site users

8.8.2.1 Contaminants measured in existing Topsoil deposits present in Zones 3 and to some extent Zone 4 are unlikely to present a risk of causing harm to human health.

8.8.2.2 A small number of measured concentrations of contaminants (lead, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene), within Made Ground deposits in the areas of Zones 2 and 4 exceed respective guideline values. Due to the relatively high concentrations measured, the UCL for lead and dibenzo(a,h)anthracene exceed the respective C4SL (u) and S4ULs for current users.

8.8.2.3 Providing the site is developed then the risk of harm being caused to current users from identified contamination is clearly a short-term issue and unlikely to require any remediation. If development does not proceed as planned, further consideration should be given to such risks and the requirement for remediation.

8.8.3 Future site users

8.8.3.1 Elevated localised concentrations of arsenic, beryllium, lead and nickel have been measured in a small number of Topsoil/natural soil samples within Zones 3 and 4. As these areas of the site have remained 'greenfield' over the years, and not been subject to past industrial activities which could have handled such contaminants, then we are of the opinion that contamination is likely to be naturally occurring. Typically, however, a significant proportion of compounds forming naturally occurring contaminants are not toxic to humans.

8.8.3.2 The existing guideline value for beryllium is based on research into the impact of **industrial** exposure, where the inhalation exposure route poses the most significant risk to end users. Indeed, the overwhelming majority of the existing literature strongly indicates that intake of beryllium orally through dermal contact has no ill health effects on humans and there is no evidence to suggest that naturally occurring beryllium poses a risk to end users.

8.8.3.3 As Zones 3 and 4 where Topsoil is present have not been subject to past industrial activities which are likely to have handled beryllium, concentrations recorded on site are likely to be naturally occurring. The average concentration of natural beryllium in the earth's crust is approximately 2 to 5mg/kg which notably exceeds the residential guideline value of 1.7mg/kg, derived by research into industrial exposure. On site, the concentrations of beryllium within soils were recorded between 1.8mg/kg to 2.5mg/kg, which reflect natural, background concentrations. On this basis, the recorded concentrations of beryllium are not considered to present a risk to end users of the site.

8.8.3.4 Similarly, concentrations of lead were measured between 250mg/kg and 320mg/kg, exceeding the C4SL (u) of 210mg/kg. It is noted that lead concentrations in the Derbyshire and Peak District area are frequently elevated above the national average. This is due to the presence of lead mineral veins in the underlying limestones, which were also mined/quarried and smelted historically. With reference to Envirocheck data presented in Appendix M, soil geochemistry mapping indicates background concentrations of lead of up to 200mg/kg at the site, however, it is noted that concentrations across the Peak District are typically higher. On this basis, the recorded concentrations of lead in Topsoil/natural soils across Zones 3 and partly Zone 4 are not considered to present a risk to end users of the site.

8.8.3.5 Similarly, the very localised elevated arsenic and nickel is likely to be associated with localised ferruginous inclusions which can be present within the limestone. This is similar to the issues experienced in Northamptonshire with arsenic, vanadium and nickel contamination, associated with the naturally deposited Northampton Sand Formation. Again, on this basis, the recorded concentrations of arsenic and nickel (the latter very marginally exceeding the S4UL) are not considered to present a risk to end users of the site.

8.8.3.6 Based on the assessment provided in paragraphs 8.8.3.1 to 8.8.3.5 above, we consider that Topsoil/naturally deposited soils at the site are unlikely to cause significant harm to human health and can be reused within the proposed development where necessary.

8.8.3.7 With reference to paragraph 8.7.6.3.3 above, a significant number of concentrations of contaminants exceed relevant guidelines for end users within Made Ground deposits across the site, largely encountered in Zone 2, and to a lesser extent in Zone 4. Notably, arsenic, beryllium and lead and a number of PAHs have been identified. Rather than naturally occurring, based on the composition of Made Ground across the areas where elevated contaminants have been measured, and based on the considerably high concentrations recorded, it is most likely to be attributed to the presence of anthropogenic material such as slag, ash and localised landfill type materials.

8.8.3.8 Based on the above, where Made Ground is present in Zones 2 and 4 such soils are likely to cause harm to the health of end users in their current condition. Proposed buildings and hardstanding will sever the pathway to such soils, however, where landscaping/gardens/POS is proposed, remedial measures will need to be implemented to render such areas fit for purpose. Typically, this could take the form of a cover system of clean Topsoil/subsoil placed in such areas. The recommended remedial measures are summarised in Section 8.9 below.

8.8.3.9 Furthermore, we have identified asbestos in 3 of 14 samples of Made Ground soils tested. Such asbestos has been identified in Made Ground soils in Zones 2 and partly Zone 4 across the site.

8.8.3.10 If Made Ground soils are not disturbed, there is likely to be a low risk of identified ACMs or free fibres causing harm to human health, including the health of current users. If such areas are developed, which they are likely to be, there remains a risk that end users are likely to come into contact with such soils and potentially disperse fibres into the air. Whilst we have not encountered asbestos in other laboratory samples tested, we cannot say for certain that ACM would not be encountered elsewhere onsite. The proposed cover system as recommended in paragraph 8.8.3.8 will serve to sever the pathway to such ACMs and reduce potential exposure.

8.8.4 Construction operatives

8.8.4.1 Analysis indicates that concentrations of contaminants measured in all Topsoil and naturally deposited soils fall below relevant guidelines for construction operatives.

8.8.4.2 Based on Section 8.7.6.4 above, a single concentration of both lead and dibenzo(a,h) anthracene have been measured above guideline values for construction operatives out of 10 Made Ground samples across the site. Based on such, providing adequate hygiene precautions are adopted at all times, we do not consider there to be a significant possibility of significant harm being caused to the health of construction operatives at the site (see Section 8.10 below). This is with the exception of risks associated with asbestos as discussed below.

8.8.4.3 If Made Ground soils are not disturbed, there is likely to be a low risk of identified ACMs causing harm to the health of construction operatives. If such areas are developed, which they are likely to be, there remains a risk that construction operatives are likely to come into contact with such soils and potentially disperse fibres into the air. Whilst we have not encountered asbestos in other laboratory samples tested, we cannot say for certain that ACM would not be encountered elsewhere onsite.

8.8.4.4 Consequently we recommend that a suitably experienced asbestos specialist is consulted to confirm the precautions that could be taken during groundworks to minimise contact/disturbance and potential release of fibres. It would also be prudent to undertake further testing of Made Ground soils across the site to determine if asbestos is present elsewhere. We would be happy to undertake such testing on further request.

8.8.5 Vegetation

8.8.5.1 Two elevated concentrations of zinc and a single elevated concentration of copper have been measured in Topsoil/natural soils, which marginally exceed the respective guideline values (see Section 8.7.7 above). Such contamination was locally present in Topsoil/natural soils within Zone 3. In our opinion, such contamination is unlikely to present a risk of causing significant harm to vegetation.

8.8.5.2 It is difficult to quantify the phytotoxity of a contaminant as large variations exist between plant tolerances, soil effects and synergistic/antagonistic reactions between chemicals. Due to the complexities of the effects of soil contamination on different plant species, we recommend that the test results presented in this report are passed to a landscape architect for the selection of suitable planting.

8.8.5.3 With reference to paragraph 8.7.7.3 above, a significant number of concentrations of contaminants exceed relevant guidelines for vegetation within Made Ground deposits encountered in Zones 2 and 4. Notably copper, zinc, lead, dibenzo(a,h)anthracene have been identified. In our opinion, such contamination is likely to present a risk of causing significant harm to vegetation. Consequently, remedial measures will need to be implemented to render such areas fit for purpose. Typically, this could take the form of a cover system of clean Topsoil/subsoil, suitably deepened where major vegetation is likely to be present, which will provide a suitable growing medium. The recommended remedial measures are summarised in Section 8.9 below.

8.8.6 Controlled waters

8.8.6.1 With reference to 8.7.8.1, groundwater at the site local to the channel of Nun Brook exhibits very marginal elevated concentrations of soluble copper (1.2µg/l compared to a guideline of 1.0µg/l). Based on leachate testing previously undertaken within landfill type Made Ground deposits in Zone 1, such soils exhibit slightly elevated concentrations of leachable copper (10µg/l), which could be the source of copper found in groundwater adjacent to the brook.

8.8.6.2 It is also noted that concentrations of soluble contaminants in a sample from the brook taken upstream from site are all below relevant guidelines. However, a sample taken downstream of the site suggests very marginal elevated concentrations of soluble copper (1.1µg/l). The copper identified in the brook could be sourced from the marginally impacted groundwater onsite, which is likely to be providing a base flow to the brook.

8.8.6.3 Based on the above, given the marginal exceedances of soluble copper identified in groundwater and surface waters, and also based on the conservatism factored into the EQS value for copper (we have not adjusted the guideline based on hardness at the site), then we consider the risk of leachable copper previously identified within landfill material to Zone 1 adversely impacting the quality of groundwater and surface waters is low.

8.8.6.4 Having now completed analysis of laboratory testing, we can now update our conceptual model which is presented in Appendix J.

8.8.6.5 Based on the conceptual model there are risks which exceed the low category which in our opinion are unacceptable and require remedial action which is discussed below.

8.9 Remedial action

8.9.1 Based on the above we recommend the following action is taken: -

a) Provision of a capping in garden and soft landscaping areas where Made Ground is present in Zones 2 and 4, deepened in areas of major vegetation as required. Details of this remediation (in the form of a statement / specification) is provided in Section 13.

b) Adoption of adequate hygiene precautions for construction operatives.

8.9.2 In addition to the above, we recommend that a suitably experienced asbestos specialist is consulted to confirm the precautions that could be taken during groundworks to minimise contact/disturbance and potential release of asbestos fibres identified in Made Ground deposits across the site. It would also be prudent to undertake further testing of Made Ground soils across the site to determine if asbestos is present elsewhere. We would be happy to undertake such testing on further request.

8.10 Risk assessment in relation to use of infiltration systems

8.10.1 With reference to Environment Agency publication '*Groundwater protection: Policy and practice (GP3)* 2012, outside of SPZ1, the EA will support sustainable drainage systems for new discharges to ground. This is subject to an appropriate risk assessment to demonstrate that ground conditions are suitable and infiltration systems do not present an unacceptable risk of promoting mobilisation of contaminants or creating new pathways for contaminant migration.

8.10.2 The permeability of the near surface weathered Eyam Limestone, Bowland shale and Bee low Limestone Formation in combination with the site located over Secondary A (Bowland Shale) and principal aquifers (limestone deposits) suggests the site is sensitive to migration of contaminants. The site is not located within or close to a source protection zone. Providing that surface water is restricted from freely migrating though Made Ground deposits, the risk of infiltration systems promoting mobilisation of contaminants at the site is considered low. All discharges to groundwater are subject to compliance with the Water Framework Directive (2000/60/EC) and Groundwater Daughter Directive (2006/118/EC).

8.11 Risk assessment summary and recommendations

8.11.1 Based on our assessments described above, we can provide the following summary and recommendations for each identified receptor.

8.11.2 Current site users

8.11.2.1 Providing the site is developed then the risk of harm being caused to current users from identified contamination is clearly a short-term issue and unlikely to require any remediation. If development does not proceed as planned, further consideration should be given to such risks and the requirement for remediation.

8.11.3 End users

8.11.3.1 Concentrations of chemical contaminants have been measured above guideline values within Made Ground deposits across the site. In such areas, we are of the opinion that the site represents a medium to high risk of causing harm to future end users of the developed site, based on current development proposals. Providing the remedial measures as outlined in 8.9 above and Section 13 are implemented, the risk of harm being caused to the health of end users is considered to be low.

8.11.3.2 We also consider that Topsoil/naturally deposited soils at the site are unlikely to cause significant harm to human health and can be reused within the proposed development where necessary.

8.11.4 Construction operatives and other site investigators

8.11.4.1 The risk of damage to health of construction operatives and other site investigators is, in our opinion, medium to high, primarily due to the presence of asbestos in Made Ground soils. Generally, risks would be minimised by taking adequate hygiene precautions on site. Such precautions would be: -

- Wearing protective clothing particularly gloves to minimise ingestion from soil contaminated hands.
- Avoiding dust by dampening the soils during the works.
- Wearing masks if processing produces dust.

8.11.4.2 Consideration will need to be given to the presence of asbestos in Made Ground soils onsite and the additional precautions that will need to be taken during groundworks to minimise contact/disturbance and potential release of fibres.

8.11.4.3 Guidance on safe working practices can be obtained from the following documents

- The Health and Safety Executive Publication *"Protection of Workers and the General Public during the Development of Contaminated Land"* (HMSO) and
- *"A Guide to Safer Working on Contaminated Sites"* (CIRIA Report 132).

8.11.4.4 In addition, reference should be made to the Health and Safety Executive. In all cases work shall be undertaken following the requirements of the Health and Safety at Work Act 1974 and regulations made under the Act including the COSHH regulations.

8.11.5 Controlled waters

8.11.5.1 Marginal elevated concentrations of leachable copper have previously been identified in landfill Made Ground soils to Zone 1, with very marginal concentrations of soluble copper identified in groundwater onsite and surface waters downstream of site. Given the marginal exceedances of soluble copper, and based on the conservatism factored into the EQS value for copper, we consider the risk of leachable copper previously identified adversely impacting the quality of groundwater and surface waters is low.

8.11.6 Vegetation

8.11.6.1 In our opinion, marginal contamination identified in Topsoil/natural soils across the site is unlikely to present a risk of causing significant harm to vegetation.

8.11.6.2 Concentrations of contaminants exceed relevant guidelines within Made Ground deposits across the site. In our opinion, such contamination is likely to present a risk of causing significant harm to vegetation. Providing the remedial measures as outlined in 8.9 above ad Section 13 are implemented, the risk of harm being caused to the health of vegetation is considered to be low.

8.12 Final conceptual model

8.12.1 On the assumption that remedial action described above has been successfully completed, we have produced a final conceptual model which is presented in Appendix J, which shows the risks for human health have been reduced to acceptable levels and the site therefore fit for purpose.

8.13 Statement with respect to National Planning Policy Framework

8.13.1 Based on investigations completed to date with respect to chemical contamination, we are of the opinion the proposed development will be safe and suitable for use for the purpose for which it is intended (without the need for any remedial action) thus meeting the requirements of the National Planning Policy Framework section 178, and compliant with the Building Regulations Part C, '*Site preparation and resistance to contaminants and moisture'.*

8.14 On Site Monitoring

8.14.1 We have attempted to identify the potential for chemical contamination on the site, however, areas, which have not been investigated at this stage, may exhibit higher levels of contamination. If such areas are exposed at any time during construction we will be pleased to re-attend site to assess what action is required to allow the development of safely proceed.

9 Gaseous contamination

9.1 Legislative framework

9.1.1 There is currently a complex mix of documentation relating to legislative and regulatory procedures on the issue of contamination and it is not considered a purpose of this report to discuss the detail of these regulations. Essentially, Government Policy is based on *'suitable for use approach',* which is relevant to both the current and proposed future use of land. For current use Part IIA of the Environmental Protection Act 1990 provides the regulatory regime (see Section 8.1 above). The presence of harmful soil gases could provide a 'source' in a 'pollutant linkage' allowing the regulator (Local Authority) to determine if there is a significant possibility of harm being caused to humans, buildings or the environment. Under such circumstances the regulator would determine the land as 'contaminated' under the provision of the Act requiring the remediation process to be implemented with the Environment Agency responsible for enforcement.

9.1.2 The Town and Country Planning (General Development Procedure) Order 1995, requires the planning authority to consult with the Environment Agency before granting planning permission for development on land within 250 metres of land which is being used for deposit of waste, (or has been at any time in the last 30 years) or has been notified to the planning authority for the purposes of that provision.

9.1.3 Building control bodies enforce compliance with the Building Regulations. Practical guidance is provided in Approved documents, one of which is Part C, '*Site preparation and resistance to contaminants and moisture*' which seeks to protect the health, safety and welfare of people in and around buildings and includes requirements for protection against harm from soil gas.

9.2 General

9.2.1 The following assessment relates to the potential for, and the effects of, gases generated by biodegradable matter. A separate, but related class of problem involves migration of vapour phase of hydrocarbons, but this is addressed under organic contamination in Section 8. The potential for the development to be affected by radon gas is considered in Section 3 above. The principal ground gases are carbon dioxide (CO_2) and methane (CH_4). The following table provides a summary of the effects of these gases when mixed with air.

Significant gas concentrations in air		
Gas	**Concentration by volume**	**Consequence**
Methane	0.25%	Ventilation required in confined spaces
	5 - 15%	Potentially explosive when mixed with air
	30%	Asphyxiation
	75%	Death after 10 minutes
Carbon Dioxide	0.5%	8 hour long term exposure limit (LTEL) (HSE workplace limit)
	1.5%	15 min short term exposure limit (STEL) (HSE workplace limit)
	>3%	Breathing difficulties
	6 – 11%	Visual distortion, headaches, loss of consciousness, possible death
	>22%	Death likely to occur

Table 9.2.1

9.2.2 Following the current Building Regulations Approved Document C1, Section 2 '*Resistance to Contaminants*' (2004 incorporating 2010 and 2013 amendments) a risk assessment approach is required in relation to gaseous contamination based on the source-pathway-receptor conceptual model procedure. We have adopted procedures described in the following reference documents for investigation and assessments of risk of the development being affected by landfill type gases (permanent gases) and if appropriate the identification of mitigation measures.

- BS10175:2011 *'Investigation of potentially contaminated sites- Code of Practice'*
- BS8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'*
- BS8485:2015 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'*
- CIRIA Report C665 '*Assessing risks posed by hazardous ground gases to buildings*' (2007)
- NHBC report No 10627-R01(04) '*Guidance on development proposals on sites where methane and carbon dioxide are present'* (January 2007)
- CL:AIRE Research Bulletin RB17 *'A pragmatic approach to ground gas risk assessment'* (November 2012)

Whilst we have followed the guidance and recommendations of BS8576, we have used BS8485:2015 to derive recommendations for protective works where considered necessary supplemented by NHBC report No 10627-R01(04).

9.2.3 An assessment of the risk of the site being affected by ground gases is based on the following aspects:

a) Source of the gas
b) Investigation information
c) Migration feasibility
d) Sensitivity of the development and its location relative to the source

9.3 Assessment of source of gases

9.3.1 General sources

9.3.1.1 The following table summarises the common sources of ground gases and parameters affecting the generation of ground gases:

Source and control of gases	
Type	**Parameters affecting the rate of gassing**
Landfills	Portion of biodegradable material, rate reduces with time
Mineworkings	Flooding reduces rate of gassing
Dock silt	Portion of organic matter
Carbonate deposits	Ground / rainwater (acidic) reacts with some carbonates to produce carbon dioxide.
Made Ground	Thickness of Made Ground and proportion of degradable organic matter
Naturally deposited soils/rocks	Portion of organic matter

Table 9.3.1

The rate of decomposition in gas production is also related to atmospheric conditions, pH, temperature, and water content / infiltration.

9.3.1.2 As the site is not within a dockland environment or an area affected by mineworkings. However the site may be affected by underlying limestone deposits, landfilling activities and near surface Made Ground soils.

9.3.2 Landfill and infilled ground sources

9.3.2.1 Waste Management Paper 27 (1991) produced by the Department of the Environment '*Control of Landfill Gases'* contains the recommendation to avoid building within 50m of a landfill site actively producing large quantities of landfill type gases and to carry out site investigations within a zone 250m beyond the boundary of a landfill site. No distinction is made between sites of differing ground conditions, but the paper does not advocate the site is safe beyond the 250m zone, dependant, of course, upon the type of landfill and potential for migration of landfill gases.

9.3.2.2 Envirocheck reports one landfill site adjacent to the northwest, known as Hogshaw refuse tip (known as Zone 1). Records indicate the site was licenced for receipt of domestic, inert, industrial and commercial wastes, and licence has now lapsed. Furthermore, the Local Authority planning portal of High Peak Borough Council, records a refuse tip in the area of the existing recreation ground to the southwest of the site (Zone 2). The extent of the tip and the type of wastes deposited are not recorded.

9.3.2.3 In addition, we have reviewed old Ordnance Survey maps and there is obvious evidence of quarrying in the area, the closest of which is 200m northwest. Such sites may have been restored with materials which could generate landfill gases.

9.3.2.4 In addition 12 BGS mineral sites are recorded within 1000m from site. The closest is located 219m to the northwest, which extracted common clay and shale. All mineral site were opencast type, used to extract clay, shale or limestone. We anticipate that these are related to the quarries recorded on the historical mapping. All extraction activities have ceased.

9.3.2.5 A number of infilled land and water bodies are also recorded on site and within 1000m of the site. A feature is recorded onsite, associated with the backfilling of Russia Mere, recorded on historical mapping between 1879 and 1967.

9.3.2.6 Based on the above, records suggest there are potential sources of ground gasses in the area worthy of further consideration.

9.3.3 Soil conditions

9.3.3.1 Laboratory testing indicates that the Made Ground soils beneath the site contain between 3.1% and 40% of organic matter. The majority of these values are from Topsoil which we do not consider to represent of significant gas generation source. However, 9 No. locations where these results are higher than 5% are from deeper Made Ground deposits, which contain between 8.6% to 40% of organic matter. Our observations during the intrusive investigation, (of Made Ground materials) indicated the presence of decomposing timber, textile, paper and fibrous material. Such deposits have the potential to produce elevated quantities of carbon dioxide and / or methane gas.

9.3.3.2 The site is underlain by soils and rocks which have a naturally high carbonate content. Following BS8576 figure 6, such soils are determined to represent a very low potential for generation of a source of carbon dioxide.

9.3.4 Source assessment summary

9.3.4.1 The following table summarises the possibility of a source of landfill type gases.

Source assessment summary		
Potential source origin	**Viability of source**	**Evidence**
Landfills	Likely	Desk study information Landfill adjacent to northwest part of site (Zone 1), and LA recorded tip in south-western part (Zone 2). Potentially backfilled quarries located within 500 of the site, in addition to infilled pond to east of site (Zone 4)
Mineworkings	Unlikely	Desk Study information Geological conditions not amenable
Dock silt	Unlikely	Site remote from dockland environment
Carbonate deposits	Unlikely	Bedrock consists of limestone, however the generation potential of this source is very low
Made Ground	Likely	Made Ground >3m thickness with TOC >5%
Naturally deposited soils/rocks	Unlikely	Soils exposed in exploratory excavations do not exhibit high concentrations of organic matter

Table 9.3.4

9.3.4.2 Based on the above it there is a possibility of a source of potential landfill gases which may affect the subject site. On this basis, it is considered necessary to consider possible pathways for migration of ground gases from this potential source to the site.

9.4 Gas migration

9.4.1 Exploratory excavations encountered predominantly coarse-grained Made Ground to depths typically between 2m to 5m within Zone 2. Made Ground was also encountered locally to depths of 1.3m to >5m in Zone 4. In our opinion, these deposits are relatively permeable and would provide little resistance to both lateral and vertical migration of landfill type gases, which would migrate directly into buildings present in such areas.

9.4.2 In addition, natural granular strata in the form of weathered bedrock (sands and gravels) and limestone is present across the site, and near surface in the area of Zones 3 and 4. It is therefore considered possible that the landfill type gases identified offsite and could feasibly migrate to the ground surface of the site, as well as migrating from areas of Made Ground, including in Zone 1 to adjacent areas of the site where such deposits are not present. Notwithstanding the above, we anticipate that the presence of localised near surface cohesive deposits could minimise vertical and lateral migration of landfill gasses within the subsurface, particularly between Zones 1 towards Zones 2/3. However, we have considered a worst-case scenario at this stage.

9.5 Conceptual model

9.5.1 Based on the above, there is a potential source of landfill type gases, and a feasible migration pathway to the site via potentially permeable Made Ground and near surface natural strata. Our conceptual model is tabled below. On this evidence we are of the opinion that the site is at risk of being affected by ground gases (carbon dioxide / methane) sufficient to potentially cause harm to human end users of the site, construction operatives or indeed buildings. On this basis, we have installed monitoring standpipes in boreholes, and implemented a monitoring regime, generally following procedures described in BS8576:2013 to quantify the risk and, if appropriate, identify mitigation measures.

Conceptual model		
Potential source origin	**Potential pathway**	**Receptors at risk**
Landfills Restored mere and number of opencast quarries – source of backfill not known. Made Ground onsite	Via near surface permeable soils and directly via Made Ground	End users Construction operatives Buildings
Table 9.5.1		

9.6 Development categorisation

9.6.1 With reference to BS8485:2015 (table 3), the proposed building type would be classified as *'Type A - Private'.*

9.7 Monitoring observations

9.7.1 Five standpipes have been installed at the site in accordance with BS8576:2013, Section 9 (refer Drawing 08). Following BS8576:2013 (Figure 6) and CIRIA Report C665 (Tables 5.5a and 5.5b) we have provisionally assessed the site as moderate to high generation potential of source ideally requiring fortnightly readings taken over a 2 to 12 month period. We can confirm we have completed 6 No. monitoring visits over a two month period.

9.7.2 We have returned to site for all of the six proposed monitoring visits to obtain measurements of landfill type gases at atmospheric conditions in the range of 955mb to 996mb and temperatures in the range of 4°C to 12°C. Essentially, within Zones 2 to 4, we detected concentrations of methane in the range of 0.0% to 0.2% and concentrations of carbon dioxide measured in the range of 0.2% to 7.9%. If flows were detected during our monitoring visits then these are recorded, but where no flow is detected then we have assumed flow at the detection limit of the monitoring equipment at 0.1l/s.

9.7.3 Within Zone 1 we detected concentrations of methane in the range of 9.6% to 24.8% and concentrations of carbon dioxide measured in the range of 14.1% to 19.9%

9.7.3 Gas monitoring results are summarised in Appendix K. It should be noted that gas measurements from location DTS06 could not be undertaken on the initial visit of the 18th February 2019 due to technical issues with the analyser at the time.

9.8 Classification of site characteristic gas situation

9.8.1 As outlined in previous sections, we have refined the following assessments based on development not being undertaken within Zone 1. Whilst we have not discussed any requirements for gas protection within Zone 1, we have discussed the presence gases in this area affecting other areas of the site.

9.8.2 Significant concentrations of landfill gases have been measured at location DTS04, situated in the main landfill site in Zone 1. Concentrations of carbon dioxide range from 18.6% to 19.9%, with methane ranging from 9.6% to 24.8%. Elsewhere onsite, concentrations of carbon dioxide range from 0.2% to 7.9%, with methane ranging from 0.0% to 0.2%.

9.8.2 Within Zone 2, in areas where Made Ground deposits exceed depths of >2m, and such deposits consist of landfill type materials (associated with the Local Authority recorded refuse tip), concentrations of methane rarely exceed 0.2%, however, concentrations of carbon dioxide have been measured between 1.8% and 7.9% (DTS24). Based on flow rates and gas screening values, the area would be classified as characteristic gas situation CS1 and traffic light colour 'Green'. However, concentrations of carbon dioxide have been measured at and above the maximum typical value of 5% for a green classification on 4 of the 6 monitoring occasions within DTS24, measured between 5.0% and 7.9%. It is acknowledged that borehole DTS19, also located in Zone 2, suggests a Green traffic light classification based on both gas screening values and actual measured concentrations. However, the response zone in this area is formed within natural soils and not the Made Ground observed across the zone. Based on the above, we recommend that the entire area of Zone 2 is classified as characteristic gas situation CS2 and traffic light colour 'Amber 1'.

9.8.3 In all other areas of the site, using test data obtained to date, Zones 3 and 4 would be classified as characteristic gas situation CS1 and traffic light colour 'Green'. Concentrations of carbon dioxide have exceeded the maximum typical value of 5% for a Green classification on one occasion to date, measured at 5.2% in borehole DTS13. Given the marginal exceedance, at this stage we do not consider it reasonable to increase the classification to CS2/Amber 1 for such areas of the site. This is likely to be associated with Made Ground deposits recorded locally in Zone 4.

9.8.4 Given the nature of the Made Ground encountered within Zones 2 and 4, and access issues experienced to date, we would recommend that further, more intensive ground gas monitoring is undertaken to fully classify these areas, particularly in the southern part of Zone 2 and along the boundary between Zone 1 (landfill) and Zones 2 and 3 to assess the potential for localised migration between such areas.

9.9 Gas protective measures – new buildings

9.9.1 Based on monitoring observations to date, development categorisation (Section 9.6 above) and the site characteristic gas situation (Section 9.8 above) and with reference to Table 4 of BS8485:2015, the area of Zones 3 and 4 are unlikely to require any gas protective measures. However, as outlined in paragraph 9.8.4 above, we recommend that this is verified by completion of further, more intensive ground gas monitoring to fully classify these areas.

9.9.2 In the area of Zone 2, the development will require gas protective measures which would achieve a '*gas protection score'* of 3.5. Lists of protective measures which each produce a score value are produced in Tables 5, 6 and 7 of BS8485:2015.

9.9.3 Furthermore, with such areas of the site being classified as 'Amber 1', then following NHBC report No 10627-R01(04) table 14.2, the following 'low level' gas protection measures are required as minimum in Zone 2: -

a) Installation of a suitable gas resistant membrane

b) Ventilated subfloor to facilitate a minimum of one complete volume change per 24 hours.

c) Gas protective measures shall be as presented in Building Research Establishment Report 414

9.9.4 It is important that the necessary gas protection measures are adopted to comply with the requirements of Local Authority Building Control and Environmental Protection; considering both the British Standard and NHBC guidance, whichever applies in precedence.

9.9.5 Again, we recommend that this is verified by completion of further, more intensive ground gas monitoring to fully classify this area of the site, particularly in the southern part of Zone 2 and along the boundary between Zone 1 (landfill) and Zones 2 and 3 to assess the potential for localised migration between such areas.

9.10 Flammability

9.10.1 Methane is a flammable gas. When the concentrations of methane in air (oxygen 20.9% by volume) are between the limits of 5% and 15% by volume, then an explosive mixture is formed. The lower explosive limit (LEL) of methane is 5% which is equivalent to 100% LEL. The 15% limit is known as the upper explosive limit (UEL), but concentrations above this level cannot be assumed to represent safe concentrations. The flammability of gas mixtures is affected by their composition, presence of an ignition source, temperature, pressure and nature of the surroundings. The explosive hazard of a flammable mixture arises from the speed of propagation of the flame in a confined space and the ability of the container to absorb the associated shock wave. The flammability range can vary depending upon differing circumstances, for example:

- When carbon dioxide concentrations of greater then 25% are present, methane is rendered non-flammable, and
- If the oxygen concentration is reduced, the limits of flammability are reduced. For example at 13.45% oxygen the LEL and UEL for methane are altered to 6.5% and 7% respectively, whilst at 13.25% oxygen the mixture is incapable of propagating a flame (refer CIRIA report 130)

9.10.2 From measurements taken to date, whilst air, methane and carbon dioxide mixtures are not potentially explosive (typically due to the lack of oxygen in the ground), there is always the possibility that explosive mixtures may occur following gas migration into enclosed spaces. For example, if methane is migrating locally between Zone 1 and Zones 2 and 3. For an explosion to occur, an enclosed space together with an ignition source is required. Clearly a sub-floor void could produce a confined space, and thus in order to minimise risks, the use of a positively pressurised clean air blanket to alter the gas mix, may produce the required solution. Such issues will require consideration following completion of the mitigation measures as described in Section 9.9 above.

9.11 Gas protective measures - construction operatives

9.11.1 Areas near landfill sites, or in carbonate rich deposits (such as limestone present beneath Zones 3 and 4) have the potential to generate both harmfully low oxygen levels and high carbon dioxide levels in confined spaces. The assessment for such situations may therefore require using gas monitors to warn of significant leaks of gas into confined spaces to minimise the risks associated with an oxygen-deficient atmosphere which could lead to asphyxiation, and/or a toxic atmosphere due to high levels of carbon dioxide.

9.11.2 During construction, we recommend any excavations/confined spaces are well ventilated and human entry is avoided. The Workplace Exposure Limits (WELs) for carbon dioxide are 5000 parts per million (ppm by volume), which is equivalent to 0.5%, for the 8-hour time-weighted average (TWA); and 15000 ppm (1.5%) for the 15-minute short-term exposure limit (STEL). Typically, oxygen deficiency alarms on gas detectors are set at 19% volume ratio (v/v). Normal air contains 20.9% oxygen. Therefore should human entry be necessary then we recommend excavations/confined spaces are monitored over short- and long-term exposure periods for both oxygen and carbon dioxide gases prior to entry to ensure levels are within acceptable concentrations or suitable breathing equipment adopted.

9.11.3 We recommend further reference is made to the following documents to minimise the risks to construction workers from ground gases:

- Health and Safety Executive Publication *"Protection of Workers and the General Public during the Development of Contaminated Land"* (HMSO)
- *"A Guide to Safer Working on Contaminated Sites"* (CIRIA Report 132)
- Health and Safety Executive Publication EH40/2005 *''Workplace Exposure Limits''*

9.12 Statement with respect to National Planning Policy Framework

9.12.1 Providing the recommendations described above are satisfactorily completed, we are of the opinion the proposed development will be safe and suitable for use for the purpose for which it is intended, thus meeting the requirements of the National Planning Policy Framework section 178, and compliant with the Building Regulations Part C, '*Site preparation and resistance to contaminants and moisture*'.

10 Effects of ground conditions on building materials

10.1 General

10.1.1 Building materials are often subjected to aggressive environments which cause them to undergo chemical or physical changes. These changes may result in loss of strength or other properties that may put at risk their structure integrity or ability to perform to design requirements. Aggressive conditions include:-

- Severe climates
- Coastal conditions
- Polluted atmospheres
- Aggressive ground conditions

10.1.2 This report section only considers aggressive ground conditions in relation to buried concrete and water pipes. Ground conditions may affect other materials but have not been considered here.

10.2 Concrete - Sulphate attack

10.2.1 Hazard

10.2.1.1 Sulphate attack on concrete is characterised by expansion, leading to loss of strength, cracking, spalling and eventual disintegration. There are three principal forms of sulphate attack, as follows:-

- Formation of gypsum through reaction of calcium hydroxide and sulphate ions.
- Ettringite formation through reaction of tricalcium alluminate and sulphite irons.
- Thaumasite formation as a result of reactions between calcium silicate hydrates, carbonate ions (from aggregates) and sulphate ions.

10.2.2 Assessment

10.2.2.1 The hazard of sulphide attack is addressed by reference to procedures described in Building Research Establishment (BRE) Special Digest 1: 2005 '*Concrete in Aggressive Ground*' to establish a design sulphate class (DS) and the '*aggressive Chemical Environment for Concrete*' (ACEC). These procedures have been followed during our investigation and are described in the following paragraphs.

10.2.3 Desk Study Information

10.2.3.1 The first step in the procedure is to consider specific elements of the desk study. These are tabulated below.

Summary of desk study information			
Element	**Interrogation**	**Outcome**	**SD1: 2005 reference**
Geology	Likelihood of soils containing pyrites	**Unlikely**	Box C6
Past industrial uses	Brownfield site	**Yes**	C2.1.2
Table 10.2.3			

10.2.3.2 A brownfield site is defined in SD1: 2005 as a site, or part of a site which has been subject to industrial development, storage of chemicals (including for agricultural use) or deposition of waste, and which may contain aggressive chemicals in residual surface materials, or in ground penetrated by leachates. Where the history of the site is not known, it should be treated as brownfield until there is evidence to classify it as natural.

10.2.3.3 Based on the above it is necessary to follow the procedures described in figure C6 ('*locations on brownfield sites except where soils may contain pyrite*') for Zones 2 and 4. For Zone 3, it is necessary to follow the procedures described in figure C4 *('natural ground sites except where soils may contain pyrite').*

10.2.4 Laboratory testing

10.2.4.1 The following table summarises ground conditions and laboratory testing.

Item	Soil type	Outcome
Soil		
Number of samples	Made Ground in (Zone 2)	4
	Weathered Bowland Shale Formation (Zone 2)	2
	Weathered Eyam Limestone Formation (Zones 3 and 4)	3
Characteristic w/s sulphate	Made Ground in (Zone 2)	58
	Weathered Bowland Shale Formation (Zones 2)	270
	Weathered Eyam Limestone Formation (Zones 3 and 4)	19
Characteristic pH	Made Ground in (Zone 2)	6.7
	Weathered Bowland Shale Formation (Zones 2)	7.9
	Weathered Eyam Limestone Formation (Zones 3 and 4)	6.3
Characteristic pH	Made Ground in (Zone 2)	0.27
	Weathered Bowland Shale Formation (Zones 2)	0.22
	Weathered Eyam Limestone Formation (Zones 3 and 4)	0.18
Characteristic sulphur (%)	Made Ground in (Zone 2)	0.33
	Weathered Bowland Shale Formation (Zones 2)	0.13
	Weathered Eyam Limestone Formation	0.14

	(Zones 3 and 4)	
TPS (%SO4)	Made Ground in (Zone 2)	0.99
	Weathered Bowland Shale Formation (Zones 2)	0.39
	Weathered Eyam Limestone Formation (Zones 3 and 4)	0.42
OS (%SO4)	Made Ground in (Zone 2)	0.88 Pyrite is probably present.
	Weathered Bowland Shale Formation (Zones 2)	0.308 Pyrite is unlikely to be present.
	Weathered Eyam Limestone Formation (Zones 3 and 4)	0.395 Pyrite is unlikely to be present.
Groundwater and leachate		
Number of samples	Made Ground in (Zone 2)	1
	Weathered Bowland Shale Formation (Zone 2)	1
	Weathered Eyam Limestone Formation (Zones 3 and 4)	1
Characteristic sulphate	Made Ground in (Zone 2)	11mg/l
	Weathered Bowland Shale Formation (Zone 2)	63mg/l
Mobility	All locations	Mobile
Surface water		
Number of samples	Nun Brook	2
Characteristic sulphate	Nun Brook – upstream 1	26 mg/l
	Nun Brook – downstream 1	33 mg/l
Table 10.2.4		

10.2.5 Disturbed ground

10.2.5.1 Results indicate that pyrite is likely to be present in Made Ground across the site. Forming foundations by, for instance, cutting a trench through naturally deposited soils or driving pre-cast concrete piles through naturally deposited soils does not, generally, create disturbed ground as defined in BRE SD 1:2005. However, any arisings resulting from replacement piling or spread footing excavations used for bulk filling on site would be classified as disturbed ground.

10.2.6 Assessment of design sulphate class (DC) and aggressive chemical environment for concrete (ACEC)

10.2.6.1 Based on the design sulphate class, characteristic value of pH and assessment of groundwater mobility, and with reference to tables C1 and C2 of SDI: 2005, the ACEC class for each soil type is presented in Table 10.2.6 below.

Summary of concrete classification				
Soil type	**Disturbed ground?**	**Consider TPS?**	**DS class**	**ACEC class**
Made Ground in (Zone 2)	Y	Y	DS-3	AC-3
Weathered Bowland Shale Formation (Zone 2)	Y	N	DS-1	AC-1
Weathered Eyam Limestone Formation (Zones 3 & 4)	Y	N	DS-1	AC-1
Groundwater/leachate samples	N/A	N	DS-1	AC-1
Surface water	N/A	N	DS-1	AC-1
Table reference 10.2.6				

10.2.6.2 Where concrete is in contact with more than one soil/groundwater source, the more onerous of design sulphate class and ACEC class should be adopted.

10.3 Concrete - Chloride attack

10.3.1 Hazards

10.3.1.1 There are a number of ways in which chlorides can react with hydrated cement compounds in concrete. These are as follows: -

- Chlorides react with calcium hydroxide in the cement binder to form soluble calcium chloride. This reaction increases the permeability of the concrete reducing its durability.
- Calcium and magnesium chlorides can react with calcium aluminate hydrates to form chloroaluminates which result in low to medium expansion of the concrete.
- If concrete is subject to wetting and drying cycles caused by groundwater fluctuations, salt crystallisation can form in concrete pores. If pressure produced by crystal growth is greater than the tensile strength of the concrete, the concrete will crack and eventually disintegrate.

10.3.2 Risk assessment

10.3.2.1 Chlorides of sodium, potassium, and calcium are generally regarded as being non-aggressive towards mass concrete; indeed, brine containers used in salt mines have been known to be serviceable after 20 years service. Depending upon the type of concrete, and the cement used up to 0.4% chloride is allowed in BS8110: Part 1.

10.3.2.2 In view of the past use of the site we consider the likelihood of elevated concentrations of chlorides in the ground is not likely to occur and on this basis have not specifically measured concentrations of chlorides and, in our opinion, the risk of buried concrete being affected by chlorides is considered low.

10.4 Concrete - Acid attack

10.4.1 Hazards

10.4.1.1 Concrete being an alkaline material is vulnerable to attack by acids. Prolonged exposure of concrete structures to acidic solutions can result in complete disintegration.

10.4.2 Risk assessment

10.4.2.1 The rate of acid attack on concrete depends upon the following:-

- The type of acid
- The acid concentration (pH)
- The composition of the concrete (cement/aggregate)
- The soil permeability
- Groundwater movement

British Standard BS8110: Part 1 classifies extreme environment as one where concrete is exposed to flowing groundwater that has a pH<4.5. The standard also warns that Portland Cement is not suitable for acidic conditions with a pH of 5.5 or lower.

10.4.2.2 The pH of the soil/groundwater was measured exceeding 5.5 and on this basis the risk of concrete being affected by acidic conditions is considered low.

10.5 Concrete - Magnesium attack

10.5.1 Hazards

10.5.1.1 Magnesium salts (excepting magnesium hydrogen carbonate) are destructive to concrete. Corrosion of concrete occurs from cation exchange reactions where calcium in the cement paste hydrates and is replaced with magnesium. The cement looses binding power and eventually the concrete disintegrates.

10.5.2 Risk assessment

10.5.2.1 In practise 'high' concentrations of magnesium will be found in the UK only in ground having industrial residues. Following BRE Special Digest 1:2005, measurement of the concentration of magnesium is recommended if sulphate concentrations in water extract or groundwater exceed 3000mg/l. Once measured the concentration of magnesium is considered further in BRE Special Digest in establishing the concrete mix to resist chemical attack.

10.5.2.2 We are not aware the site has been subject to any manufacturing processes which would have included magnesium containing compounds, and in addition sulphate concentrations did not exceed 3000mg/l, on this basis we have not measured the concentration of magnesium in soils at the site and would consider the risk of soils at the site promoting attack on concrete is considered low.

10.5.2.3 BS EN 206-1:2000 '*Concrete - Part 1: Specification, performance, production and conformity*' does, however, provide exposure classes for concrete in contact with water, with varying concentrations of magnesium for the design/specification for concrete mixes. Based on groundwater measurements made at the site to date, there is a low risk of concrete for traditional foundations being in contact with groundwater during its life, thus we have not measured the concentration of magnesium in groundwater samples. If piled foundations are utilised onsite it is likely they will come into contact with groundwater, therefore, we recommend that the concentration of magnesium is measured in such areas of the site.

10.6 Concrete - Ammonium attack

10.6.1 Hazards

10.6.1.1 Ammonium salts, like magnesium salts act as weak acids and attack hardened concrete paste resulting in softening and gradual decrease in strength of the concrete.

10.6.2 Risk assessment

10.6.2.1 UK guidance is not available on the concentration of ammonium which may affect concrete. BS EN 206-1: 2000 '*Concrete - Part 1: Specification, performance, production and conformity*' does, however, provide exposure classes for concrete in contact with water with varying concentrations of ammonia for the design/specification for concrete mixes.

10.6.2.2 Based on groundwater measurements made at the site to date, there is a low risk of traditional concrete foundations being in contact with groundwater during its life, thus we have not measured the concentration of ammonia in groundwater samples. In addition, the site has no history which provides evidence of the uses of ammonia on site, and in overall conclusion the risk of concrete being affected by ammonia is considered low. However, if piled foundations are utilised onsite it is likely they will come into contact with groundwater, therefore, we recommend that the concentration of ammonia is measured in such areas of the site.

10.7 Plastic Pipes

10.7.1 Hazards

10.7.1.1 Plastic pipes are predominantly manufactured from PVC and PE but other materials can be used. In general, they perform well but it is known that chemical attack and permeation of contaminants through the pipes can result from use in contaminated land. A published review on plastic pipes reports the following:-

- Polyethylene (PE) - good resistance to solvents, acids and alkalis
- Poly vinyl chloride (PVC) - most common form of pipe. Good general resistance to chemical attack but can be attacked by solvents such as ketones, chlorinated hydrocarbons and aromatic polypropylene (PP) - chemically resistant to acids, alkalis and organic solvents but not recommended for use with storing oxidising acids, chlorinated hydrocarbons and aromatics.

- Poly vinylidene fluoride (PVDF) - inert to most solvents, acids and alkalis as well as chlorine, bromide and other halogens
- Polytetrafluoroethylene (PTFE) - one of the most inert thermoplastics available. PTFE has good chemical resistance to solvents, acids and alkalis

A survey carried out by the Water Research Centre (WRc) on reported incidents of permeation (more than 25), only two involved PVC with these incidents relating to spillages of fuel.

10.7.2 Assessment

10.7.2.1 A survey carried out by the Water Research Centre (WRc) on reported incidents of permeation (more than 25), only two involved PVC with these incidents relating to spillages of fuel.

10.7.2.2 The UK Water Industry research (UKWIR) have published a document entitled *'Guidance for the selection of Water supply pipes to be used in Brownfield sites'.* The publication defines brownfield sites as

> *'Land or premises that have been used or developed. They may also be vacant, or derelict. However, they are not necessarily contaminated'*

10.7.2.3 The subject site has not previously been developed however, it would appear that it has been used, and on this basis could potentially be considered brownfield in accordance with the UKWIR document. Following the preliminary risk assessment procedures described in the UKWIR document however, (paragraph 2.4.2) there is no evidence to indicate that chemicals have ever been used or stored on site or adjacent to the development. However, in Zones 2 and 4 significant deposits of Made Ground have been identified and based on the concentrations of chemical contaminants measured to date, is considered likely that there will be a requirement to use barrier water supply pipes in such areas. We recommend Severn Trent however is consulted on this to gain their opinion and requirements.

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11 Landfill issues

11.1 Disposal of soils off site

11.1.1 Disposal of waste soils must comply with the Landfill Directive and amendments to the *'Landfill (England and Wales) Regulations'.* Essentially, this requires the 'waste producer' to classify soils for off-site disposal to an appropriately licensed landfill facility. Laboratory testing on soils from the site would be required to allow such classification in accordance with current Environment Agency waste acceptance criteria and procedures. We can carry such testing and an assessment of soil classification for disposal on further instructions.

11.2 Landfill tax

11.2.1 Disposal of soils to landfill sites is normally subject to landfill tax with rates varying from year to year based on government policy. Current information on rates of landfill tax can be obtained from the HM Revenue and Customs website. (www.hmrc.gov.uk)

11.3 Reuse of Soils - Materials Management Plans

11.3.1 Where soils are to be moved and reused onsite, or are to be imported to the site, a Waste Exemption or an Environmental Permit is required.

11.3.2 An alternative is the use of a Materials Management Plan (MMP) to determine where soils are and are not considered to be a waste. By following *'The Definition of Waste: Development Industry Code of Practice'* published by CL:AIRE (produced in 2008 and revised in March 2011), soils that are suitable for reuse without the need for remediation (either chemical or geotechnical) and have a certainty of use, are not considered to be waste and therefore do not fall under waste regulations. In addition, following this guidance may present an opportunity to transfer suitable material between sites, without the need for Waste Exemptions or Environmental Permits.

11.3.3 MMPs offering numerous benefits, including maximising the use of soils onsite, minimising soils going to landfill and reducing costs and time involved in liaising with waste regulators.

11.3.4 We can provide further advice on this and provide fees for producing a Materials Management Plan on further instructions.

12 Further investigations

12.1	Further investigations

12.1 At this stage we consider further investigations to be necessary once development proposals have been finalised. Remedial measures (including verification and validation) related to chemical and gaseous contamination of the site are presented in Section 13. We advise that that further investigation should include as a minimum;

- Once development proposals are confirmed, we recommend that more detailed and plot specific investigations are undertaken to validate our foundation/floor slab assessments. Further details are provided in Section 7.
- Should piled foundations be selected then we recommend a supplementary borehole investigation be carried out in such areas to explore ground conditions at depths beyond possible pile lengths and provide geotechnical parameters for the design of the piles.
- During any further investigations within Zone 2, a detailed assessment should be made of the presence of below ground obstructions associated with the historical railway infrastructure where access has not been gained to date.
- Given the access restrictions and variable nature of ground conditions encountered in Zone 4, we recommend that further plot specific intrusive investigations are undertaken to confirm the composition of soils and determine an appropriate foundation strategy.
- Similarly, we recommend that further intrusive investigations are undertaken in Zone 2 where access could not be gained and verify foundation assessments accordingly.
- Non-intrusive geophysical surveys are undertaken by a specialist across the area of Zones 3 and 4 to determine if there are any anomalies near surface which could indicate the presence of dissolution features.
- Assessment and classification for reuse of site won soils onsite, in addition to offsite disposal to landfill.
- It would also be prudent to undertake further testing of Made Ground soils across the site to determine if asbestos is present elsewhere.
- Further area specific gas monitoring is undertaken within Zone 2 particularly to the southwest where the LA recorded refuse tip is present) and Zone 4 to fully classify such locations where significant Made Ground is present and confirm that an Amber 1/CS2 classification is appropriate.
- Where piled foundations are utilised onsite, the concentrations of magnesium and ammonia should be measured in groundwater.
- Further, more intensive, on site infiltration testing should be carried to determine if such systems are viable.
- Reassessment of CBR values is undertaken following finalisation of cut and fill levels across the site.

12.2 We would be happy to provide fee proposals for any of the above identified items on further instruction.

12.3 In addition to the above, we would also recommend that a suitably experienced asbestos specialist is consulted to confirm the precautions that could be taken during groundworks to minimise contact/disturbance and potential release of fibres. Furthermore, such a specialist could provide further advices on the disposal of ACMs identified at the site.

12.4 We recommend that a Japanese Knotweed remedial specialist is contacted for advice and measures to deal with the significant stands of Japanese Knotweed suspected to be present around the site (in Zone 2) prior to construction and commencement any earthworks activities.

13 Remediation strategy and specification

13.1 Introduction

13.1.1 This remediation statement has been produced with a view to isolating and clarifying remedial measures outlined in our main ground investigation report for the site. The objective of remediation works described in this report is to render the site *'fit for purpose'* in relation to the proposed development.

13.1.2 We understand the development will comprise the construction of residential houses, with gardens along with landscaped and parking areas. Garden and landscaped areas will be accessible to children resident in the completed development.

13.1.3 This remediation statement only considers the process of remedial action in terms of addressing contamination recognised to date. If during development, contamination not previously identified, is found to be present at the site, then an addendum method statement will be required, and the appropriate measures taken on site.

13.1.4 All sampling and laboratory analysis associated with the recommended remediation will be undertaken following nationally recognised guidelines and standards that are appropriate at the point of investigation. Laboratory analysis must be commissioned with testing houses that are suitably experienced and are MCERTS accredited with a quality assurance system.