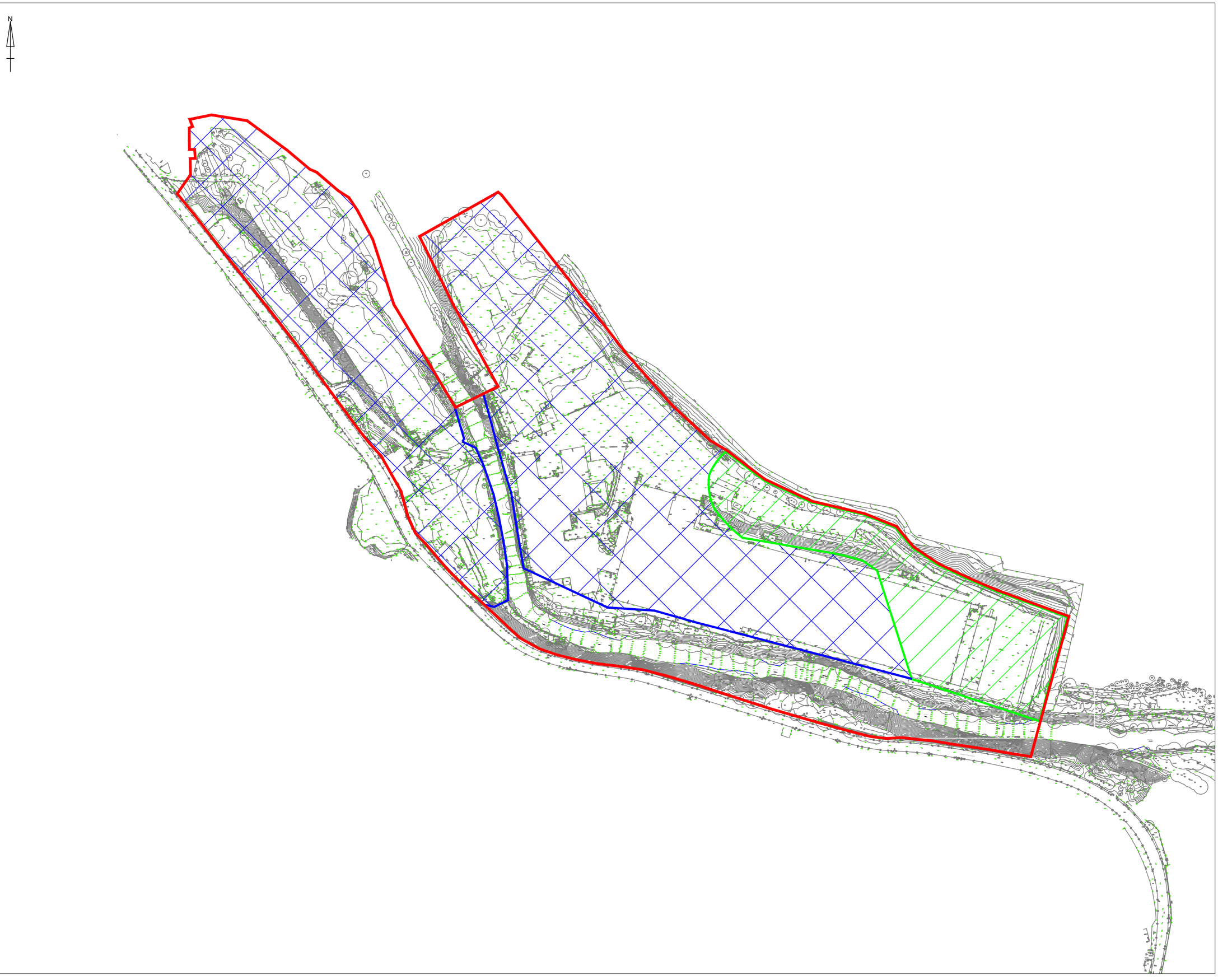

NOTES

Shallow Spread Foundations/
Trench Fill

Piled Foundations
(pre-bored where necessary)

REVISION	
0	For Information
A	>>
B	>>
C	>>
D	>>

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CLIENT

CEG

SITE

Oughtibridge Mill

DRAWING TITLE

Indicative Foundation Zoning Plan

DRAWING NO.	REVISION NO.
C6485A RevA/RS/05	**0**
DRAWN BY: **SM**	APPROVED BY: **NJ**

DATE	SCALE	PAPER SIZE
October 2017	**1:2000**	**A2**

APPENDIX B

SUPPORTING INFORMATION / GUIDANCE

REPORT C6485D REV A
OCTOBER 2017

SETTLEMENT REPORT

of land at
OUGHTIBRIDGE MILL

prepared for
CEG

REPORT NUMBER:	C6485D RevA	**REPORT STATUS:**	FINAL
REPORT TYPE:	SETTLEMENT REPORT		
REPORT DATE:	OCTOBER 2017		
SITE:	LAND AT OUGHTIBRIGE MILL		
PREPARED FOR:	CEG		
PREPARED BY:	Sirius Geotechnical Russel House Suite 2 Mill Road Langley Moor Durham DH7 8HJ	Tel: 0191 378 9972 Fax: 0191 378 1537	

SETTLEMENT REPORT

of land at

OUGHTIBRIDGE MILL

Prepared for

CEG

CONTENTS

APPENDICES

APPENDIX A FIGURES AND DRAWINGS

Drawing No.	Title	Scale
C6485D RevA/01	Site Location Plan	1:50,000
C6485D RevA/02	Site Zoning Plan	1:2000 (at A2)
C6485D RevA/03	Indicative Rockhead Countour Plan	1:2000 (at A2)
C6485D RevA/04	Indicative Alluvium Thickness Zoning Plan	1:2000 (at A2)
C6485D RevA/05	Indicative Made Ground Thickness Zoning Plan	1:2000 (at A2)

NTS: Not to Scale

1. INTRODUCTION

Sirius Geotechnical Ltd ("Sirius") was commissioned by CEG to undertake an assessment of settlement of land at Oughtibridge Mill, Oughtibridge, Sheffield (the "site"). This report is based on information provided by CEG's consultancy team; including Sirius. Although no outline development levels have been provided to Sirius to date, it is assumed they will take account of minimum acceptable flood levels.

The risk settlement poses to different structures within the development, in particular adoptable highways, residential plot external areas (i.e. gardens and driveways) and public open space has been evaluated as part of this assessment. Settlement evaluation is based broadly on assumed proposed levels with congnisance of additional build up for highway/plot construction and cover soils in gardens.

The objective of this report was to assess the likely/predominant modes of settlement within the site. Where significant settlement is expected, to then propose mitigation measures to deal with any excessive long term settlements, which may affect aspects of the development, for example highways, drainage and external areas around residential dwellings.

Ground investigation data has been used in this assessment, which comprises the following:

- Targeted ground investigation at the site (Sirius report ref: C6485, dated July 2015) within the north western site area.
- Geoenvironmental Site Assessment (Sirius report ref C6485A Rev A, dated March 2016)
- Bridge Ground Investigation Report (Sirius report ref C6485B, dated July 2016
- Retaining Wall Ground Investigation Report (Sirius report ref C6485C, dated July 2016)

This report reviews the factual information available during this assessment, interpretation of the data obtained and recommendations relevant to the defined objectives.

It has been assumed in the production of this report that the site as a whole is to be developed for a low rise residential with gardens end-use. In addition, it is assumed that ground levels will consider minimum flood levels, with congnisance of additional build up for highway/plot construction and cover soils in gardens. If this is not the case, then amendments to the recommendations made in this report may be required.

The comments and opinions presented in this report are based on the findings of previous ground investigation reports/ data performed by both Sirius and, to a limited extent other parties. There may be other conditions prevailing on the site which have not been reviewed by this assessment and as such have not been taken into account by this report. Responsibility cannot be accepted for any conditions not revealed by this investigation. Any diagram or opinion on the possible configuration of strata, contamination or other spatially variable features between or beyond investigation positions is conjectural and given for guidance only. Confirmation of ground conditions between exploratory holes should be undertaken if deemed necessary. Evaluation of gas and groundwater is based on observations made at the time of the investigations and monitoring visits. It should be noted that groundwater levels may vary due to seasonal and other effects.

This report has been prepared for the sole use of CEG. No other third party may rely upon or reproduce the contents of this report without the written approval of Sirius. If any unauthorised third party comes into possession of this report, they rely on it entirely at their own risk and the authors do not owe them any Duty of Care or Skill.

2. SITE DETAILS AND DESCRIPTION

Table 2.1 Current Site Overview

Location	The site is located off Main Road and Langsett Road North, Oughtibridge, approximately 10km north west of Sheffield City Centre. A site location plan is included as Drawing No. C6485D RevA/01 within Appendix A.
National Grid Reference	430223mE, 393975mN.
Topography and Features	The site is irregular in shape, with approximate dimensions of 900m in length and 200m in width, and comprises a number of existing and recently demolished structures, associated with the former Oughtibridge Paper Mill. The southern boundary of the site runs approximately north west-south east parallel to Langsett Road. The River Don runs centrally through the site, bisecting it into two portions. The river flows towards the south east. A former mill race, and recently infilled reservoirs and ponds were historically present within the north western part of the site. A bridge suitable for vehicle access is present across the river. For the purposes of this report, the site has been zoned into six distinct areas (A to F inclusive), which have been delineated based on a number of criteria, including A) ground conditions, B) site topography and C) former land use. The six areas are indicated on Drawing No. C6485D/02 included within Appendix A of this report. The extent and condition of the six areas are described in further detail below. ***Mill (Areas A, B and C)*** The mill area forms a broadly rectangular shaped plot within the eastern / south eastern portion of the site. The area is bound by the River Don to the south and south west and by woodland to the east and south east. The former landfill area lies adjacent to this area to the north west.

	The mill area is accessed via the vehicle bridge, which crosses the River Don in the south western corner of this area. This area of the site broadly slopes downwards from north to south east (down toward the River Don) with a fall of around 5m. Locally, within the central portion of this area there is a *circa* 220m long and 5m high densely vegetated slope. The difference in levels indicates that cut and fill operations may have historically been undertaken to form a development platform for the mill buildings. The mill area comprises a large un-occupied single to three storey high industrial unit with associated office buildings, and a service yard recorded to the south eastern portion. The majority of the mill area is covered by concrete or asphalt hardstanding, with the exception of an area of rough grassland in the south eastern portion. ***Former Landfill (Area D)*** The former landfill area forms an irregular shaped plot of land within the north eastern portion of the site. The area is bound by the River Don to the south west, an area of woodland to the north and east and the mill area to the immediate south. The area is generally level, although rising gently from the south west to the north eastern corner by approximately 2m. The area comprises two large gated compounds, which are accessed from the mill area. The compound within the central eastern portion of the area is covered by concrete hardstanding, whilst the compound within the northern portion is covered mainly by rough grassland and occasional shrubs. Concrete hardstanding is also present within the western landfill area. A number of small, single-storey brick buildings are present within the central portion of this area and an electrical sub-station recorded to the southern perimeter of this area.

	North West (Area E) - Infilled former effluent tanks, reservoirs and mill race This area of the site is bound by Main Road to the west, the River Don to the east, former buildings to the south and residential properties to the north. An access road from Main Road is present within the south western portion of this area, which slopes downwards into the main site. It is understood that this area of the site contained the former effluent treatment plant and associated facilities, which included three reservoirs and two circular effluent tanks. A historical mill race is also recorded. As part of the closure of the mill, it is understood that the former structures may have been partly broken out and were then infilled. However, a remnant concrete structure is recorded within the southern portion of this area, which is believed to represent part of the former mill race. This plot of land contains two levels. An upper level, to the west, approximately 4m higher (at an elevation commensurate with Main Road), than the rest of this area to the east. The lower level, was once occupied by the former structures and is adjacent to the River Don which flows to the east. As a result, there is a steeply vegetated slope between the two levels, which would indicate that an element of cut and fill earthworks has occurred. The upper level is covered by asphalt hardstanding formerly used for car parking and the lower level is covered by mixed granular and cohesive fill materials. It should be noted that this area was noted to be heavily waterlogged during elements of the various intrusive investigations undertaken by Sirius. ***South West (Area F) - Former buildings / machinery / engine house*** The south western area is bound by the River Don to the east and Langsett Road North / Main Road to the west, with Area E located to the north.

	This area of the site is formed over two levels: the upper level forms the site entrance and bridge access to the mill area; the lower level comprises the floor slabs of the former buildings, adjacent to the River Don. A *circa* 5m high sloped embankment, comprising demolition rubble, has been formed to provide vehicular access between the upper and lower levels of this area. A number of retaining wall structures, many supporting Langsett Road North/ Main Road, are recorded along the south western portion of this area. These wall are associated with the former building frontages, owing to an approximate 6m elevation difference from this area to Langsett Road North / Main Road. A steep vegetated slope is located along the southern site boundary, retaining the off-site highway at the crest and forming the river banking at the base. No pedestrian / vehicle access is currently possible along the toe of the slope. The lower level of this area is generally covered by mixed concrete hardstanding and demolition rubble associated with the former buildings that occupied this portion of the site. A number of un-occupied single to two storey brick built buildings are present along the south western boundary of the site. In the north western part of this area there is a single to three storey building currently occupied by site security. A weighbridge is located within the northern area.
Approximate Site Area	13 hectares.
Site Boundaries	The site is bordered by woodland to the north and east, Main Road / Langsett Road North to the south and residential properties and a public house to the north / north west.
Current Land Use	Disused.

3. SITE SETTING

3.1. Introduction

Published geological and historical data, relevant to the context of this report, has been reviewed and summarised. A full review of relevant information relating to the environmental setting of this site is provided with Sirius Geoenvironmental Appraisal Report C6485A Rev A, dated March 2016.

3.2. Site History

To establish the history of the site, extracts of Ordnance Survey (OS) plans dated from 1855 to 2014 have been examined.

Table 3.1 provides a summary of the salient points relating to the history of the site with respect to the proposed future end use. It is not the intention of this report to describe in detail all of the changes that have occurred on or adjacent to the site, only those pertinent to the proposed development.

Table 3.1 Site History

Map Dates	On-Site Features
1855	The site is shown to be developed with a small, centrally located building denoted as Spring Grove Paper Mill. Features associated with the river are indicated within the site, including a water wheel (Spring Grove Wheel), a sluice, a possible mill race and un-named ponds. Spring Grove Mill (corn) is shown within the north western area of the site.
1894 - 1956	The on-site paper mill is shown to have been expanded towards the south east of the site, along with development of a mill race, three defined reservoirs and a large pond within the north western area of the site. The mill race appears to the south east of the paper mill, partly culverted. An area of earthworks is evident directly south west of the reservoirs and pond (adjacent to Main Road along the southern boundary). A new railway siding is shown within the north of the site, connecting the off-site Manchester-Sheffield railway to the paper mill. The railway is shown to cross the river over a bridge within the site. The remainder of the eastern and northern areas of the site are shown as undeveloped woodland. Further expansion and development of the paper mill is evident on the 1905-1906 OS map. Spring Grove Mill (corn) is no longer denoted.

Map Dates	On-Site Features
1966 - 1970	The site is shown to be largely cleared of woodland, leaving rough ground with localised vegetation / trees. Two new buildings are evident adjacent the off-site road within the north west of the site. An area of earthworks is shown within the north east of the site.
1981 - 1992	Significant extension of the paper mill is shown centrally within the site, along with new foot bridges across the river. A large refuse area / slag heap is shown towards the north east of the site, in addition to new railway sidings and un-named buildings. Circular and irregularly shaped structures are indicated within the pond in the north of the site, which are considered to represent effluent tanks. An area of earthworks is evident to the east of the new mill area, considered to indicate cut and fill operations to form a level development plateau. The most eastern area of the site is shown as mixed woodland.
2006 - 2014	Extension of the mill towards the east is evident, along with removal and clearance of the railway sidings across the site. Areas of earthworks is evident along the route of the former sidings. The refuse area is no longer shown. The two buildings within the north west of the site are no longer shown. A rectangular structure is shown to the north of the effluent tanks. Two chimneys are evident within the site.

Although the area of refuse in the north east of the site is not indicated on historical OS maps until 1981, available historical aerial photographs appear to indicate that the landfill was in use prior to 1969.

The western areas of the site have since undergone partial demolition and clearance, including the mill buildings within the south west and effluent tanks within the north west of the site. The former mill race and reservoirs were infilled in approximately 2014 as part of decommissioning works.

3.3. Published Geological Information

A summary of available published geological information is provided in Table 3.2 below.

Table 3.2 Geological Summary

Sources of Information	BGS 1:50,000 scale geological map (Sheet 87 - Barnsley). BGS Geology of Britain Viewer and Lexicon (available online).
Made Ground	None recorded on the published maps but likely to be present given the history of the site.
Drift Geology	Alluvium is shown to be present centrally within the site, adjacent to the river. Alluvium is described by the BGS as comprising '*Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present'.*
Solid Geology	The site is shown to be underlain by Carboniferous Millstone Grit Formation, described by the BGS as comprising *'fine- to very coarse-grained feldspathic sandstones, interbedded with grey siltstones and mudstones, with subordinate marine shaley mudstone, claystone, coals and seatearths'*. An un-named sandstone unit (within the Millstone Grit Formation unit) is shown to be present beneath the north west of the site. An approximate east-west orientated fault is conjectured within the south of the site. Coal seams (including Pot Clay and Soft Bed coal) associated with the stratigraphically younger Lower Coal Measures are indicated approximately 250m to the north and 150m to the south of the site, dipping away from the site.
Mining and Quarrying	A CA mining report included in the 2014 WSP preliminary appraisal report states that: • *"The property is not within the zone of likely physical influence on the surface from past underground workings".*

	The CA report references a disused adit or mineshaft approximately 300m to the east of the site. Grange Lane Colliery is recorded within the Envirocheck report as a BGS recorded mineral site (located 116m to the north of the larger site area), associated with underground mining of Silkstone Coal. This record is recorded as 'ceased'. Former sandstone quarries exist to the south of the site, which are recorded by the BGS as 'ceased' mineral sites. These correlate with the outcrop of the Rough Rock Sandstone.

4. PREVIOUS INVESTIGATION FINDINGS

Previous investigations have been undertaken by other parties within various areas of the site, as listed below. Salient points are summarised below.

Report on Ground Investigation dated March 2001, prepared by Structural Soils Limited.

A factual ground investigation was undertaken by Structural Soils Limited on behalf of Ove Arup and Partners at the site in January 2001. Fieldworks comprised seven cable percussion boreholes (ref. BH101 to BH104, BH106, BH106A and BH106B), five window sample boreholes (WS101 to WS104 and WS109) and nine machine excavated trial pits (TP101 to TP108 and TP110).

Hydrocarbon Contamination Assessment dated February 2005 prepared by RPS Health, Safety and Environment.

Additional site investigation was undertaken by RPS in January 2005. Fieldworks comprised four cable percussion boreholes to depths of between 2.1m and 6.4m below ground level (bgl) (BH201 to BH204) and two trial pits (TP201 and TP202).

Findings of Diethanolamine Dye Investigation dated 22nd December 2010, prepared by URS.

URS were commissioned in 2010 to undertake targeted ground and groundwater investigation at the site, within an area formerly occupied by a bunded dye store located within a warehouse.

URS undertook the intrusive investigation in December 2010, comprising the drilling of three window sample boreholes (MW101 to MW103) to a maximum depth of 7.0m bgl.

Granular made ground (comprising ashy fill) was recorded within each borehole, to a maximum depth of 5.6m bgl, underlain by ‘soft grey / dark grey / black silt / sandy clay’ within MW102.

Preliminary Environmental and Geotechnical Risk Assessment dated September 2014, prepared by WSP UK Ltd.

WSP was commissioned by Capita Property and Infrastructure (Capita), on behalf of their client SCA, to undertake a preliminary appraisal (desk study) of the proposed development site (referenced as ‘Lot 8A’), which formed part of a wider site area (divided into twelve ‘lots’).

At the time of reporting, WSP described the presence of *'three reservoirs immediately adjacent to the River Don, bounded to the north and south by two sluice gates, beyond which is a former effluent tank and former slurry pond. The use of the reservoirs is unknown, but they may have been pulp settlement tanks'*, within the north west of the site. These features have since been decommissioned, removed and infilled.

Geoenvironmental Assessment dated April 2015, prepared by WSP UK Ltd.

WSP was instructed by Capita to undertake an intrusive ground investigation at the site.

As part of the site features description, WSP stated: *'At the time of the 2014 / 2015 investigations, a demolition programme was underway as part of the proposed re-development. Demolition has commenced in the north west and south west of the site…. As a consequence of the demolition works, building rubble makes up the surface material in the south west of the site, to the west of the River Don'.*

'During the 2014 investigation, a large amount of import material was being placed in the north west of the site infilling the former ponds and raising the original ground level'.

Fieldworks were undertaken initially in November 2014, with a second phase in February 2015. In total, investigation works comprised nine rotary boreholes (BH201, BH202, BH202A and BH203 to BH208), nine machine excavated trial holes (TP204 to TP212, although the logs for TP209 and TP210 are omitted from the report) and two hand dug pits (HP201 and HP202). In summary, the ground investigation encountered a variable thickness of made ground overlying either alluvial soils in turn underlain by weathered Millstone Grit strata, or directly underlain by weathered Millstone Grit. Made ground was encountered to depths of between 0.2m and 6.0m bgl across the site, generally found to be deeper within the landfill and within the north western areas of the site. Made ground was recorded by WSP generally to comprise gravels and cobbles of concrete, brick, sandstone and coal. Natural superficial soils interpreted as alluvial soils by WSP were recorded to comprise *'soft or soft to firm sandy clays, locally organic in nature, which ranged in thickness between 1.2m to 3.3m. The results of laboratory testing indicate the alluvium to be low to intermediate plasticity'*. Weathered Millstone Grit strata were recorded by WSP within the majority of exploratory holes, recorded as comprising '*gravelly clay or clayey gravel with varying cobble and boulder content'*.

Factual Environmental Ground Investigation Report - Retained Land, dated February 2015, prepared by Arcadis EC Harris.

Arcadis was commissioned by Georgia-Pacific LLP to undertake a geoenvironmental ground investigation and present a factual report on an area of land retained at the site. The retained land predominantly comprised the disused landfill that was reported to receive mixed industrial waste from the operation of the Oughtibridge Mill. It is understood that the land was retained by Georgia Pacific when the active Oughtibridge Mill site was sold in 2012.

The retained land is located within the northern boundary of the site, approximately 50m to the east of the River Don. The site is bordered by woodland on the eastern and northern sides and the mill site to the south. The defined area also included woodland that was not investigated during their works.

Fieldworks were undertaken in November 2014 and comprised the drilling of four cable percussion boreholes (BH101, B102A, BH103 and BH104) to a maximum depth of 8.0m bgl, including the installation of monitoring wells, and the excavation of nine trial pits (TP101 to TP107, TP109 and TP110) to a maximum depth of 3.0m bgl.

Ground conditions were recorded to comprise made ground to depths of between 0.9m and 5.15m bgl, comprising ‘assumed landfill material’ and ‘reworked natural ground’. The ‘assumed landfill material’ was identified in all of the exploratory holes. In general, this was encountered as gravelly sand, sandy gravel and sandy gravelly clay with cobbles and boulder-sized materials, which included concrete, bricks, ash, clinker and plastics. In addition to the general waste, a white jelly-like substance with a ‘strong chemical odour’ was encountered at 1.0m bgl in TP101 and a ‘large amount of compressed paper’ was identified at 2.0m bgl in TP104. A hydrocarbon odour was noted at 0.75m bgl in BH101 and 0.7m bgl in BH102A. ‘Reworked natural ground’ was identified in each borehole, underlying the landfill material. This generally consisted of sandy, gravelly clay with sandstone and occasional clinker.

Natural soils were recorded within each borehole underlying the made ground soils. Natural soils were recorded to comprise firm sandy clay with localised organic content, typically overlying clayey gravel with cobbles.

5. GROUND CONDITIONS AND MATERIAL PROPERTIES

5.1. Strata Profile

Data from the aforementioned reports has been reviewed to assess if there are any major discrepancies with the recent Sirius ground investigations. Data was found, generally, to be in accordance with the findings of the recent Sirius ground investigations. In light of the issue of reliance on information available from previous reports, this settlement assessment has been based on information gained from the recent Sirius investigations only.

A complete record of all the strata encountered as part of the June 2015 and the November 2015 to July 2016 Sirius investigations are given within the relevant ground investigation reports listed within Section 1 of this report.

A summary of the strata profile encountered within each of the Six Areas, are provided within Tables 5.1 to 5.6 below.

Table 5.1 Strata Profile – Former Mill (Area A)

Strata	Depth Range (Thickness Range)	Description and Comments
Made Ground	Ground level (0.35m to 2.0m)	Made ground was recorded across this area, generally ranging in thickness from 0.35m to 0.9m, though locally noted to be 2m thick in SBH01, close to the bank of the River Don. The made ground in this area consisted of a surface layer of concrete or asphalt hardstand, underlain by granular material, often described as limestone sub base. A relatively thin layer of cohesive made ground was noted in STP07 and SWS06, 0.2m and 0.75m thick, respectively. Granular made ground typically comprised very sandy limestone gravel sub base, or sandy silty gravel/ clayey gravelly sand and sand and gravel. The gravel fraction outwith the sub base typically comprising concrete, brick, sandstone, mudstone, and within STP17, there was occasional wood fragments and re-bar,
Alluvial Soils	0.35m to 2.0m (2.35m to 4.30m, where proven)	Cohesive alluvial soils were recorded underlying made ground soils across the southern end of this area only. Cohesive alluvial soils generally comprised a variable mix of soft through to stiff consistency, low, to medium strength, clays. Granular alluvium was noted in SBH01 only.
Completely Weathered Millstone Grit Formation	0.40m to 6.30m (NR)	Natural residual soils, were found below either alluvial soils to the south, or at shallow depth directly beneath made ground in the northern part of this area. The residual soils were recorded to be predominantly cohesive,

Strata	Depth Range (Thickness Range)	Description and Comments
(Residual Soils)		with granular material encountered in SBH01 only. The cohesive residual soils were described as stiff to very stiff, locally firm in consistency, sandy clay with gravel sized fragments of sandstone and mudstone. The granular residual soils comprised very dense clayey sandy gravel of mudstone.

NR - not recorded

Table 5.2 Strata Profile – Former Mill (Area B)

Strata	Depth Range (Thickness Range)	Description and Comments
Made Ground	Ground Level (0.35m to 3.6m, where recorded)	Made ground initially comprised a surface layer of either asphalt or concrete hardstand. The reinforced concrete hardstanding within SWS08, SWS45, STP18 and STP23 was unable to be cored / broken, and as such the window samples / trial pits were terminated at depths between 0.10m and 0.30m bgl. Typically the made ground was deeper within the northern portion, toward the former landfill area, becoming thinner to the south east. It also appears that an element of regrading had occurred in the area of the existing buildings, to enable the creation of a level development platform for the buildings themselves. Granular made ground appeared to predominate across the area, typically comprising very loose, to medium dense, sandy gravel, clayey gravelly sand, and sand and gravel. The gravel fraction typically comprising concrete, brick, sandstone and mudstone, and locally, wood, metal, re-bar, clinker, asphalt, limestone and slate. Cohesive fill was recorded to typically comprise soft to firm, sandy clay with gravel of brick, concrete, sandstone, and locally ash, slate, wood, charcoal, clinker and mudstone. A possible reworked alluvial soil was encountered within two exploratory hole locations (STP11 and SWS09) extending to depths between 1.50m and 2.70m bgl, comprising very soft very gravelly sandy clay with occasional organic inclusions. Within a number of the exploratory hole locations, low content of cobbles and boulders were recorded. Frequent concrete and sandstone obstructions were also encountered within the made ground soils A number of the window sample boreholes and trial pits were terminated within the made ground soils and subsequently did not prove the full thickness of the fill materials.

Strata	Depth Range (Thickness Range)	Description and Comments
Alluvial Soil	0.35m to 3.6m (0.8m to 5.4m, where recorded)	Cohesive alluvial soils were recorded underlying made ground soils across the majority of the former mill area. Cohesive alluvial soils generally comprised soft to firm (locally very soft or stiff) sandy clay / silt with gravel sized fragments of sandstone. Locally the alluvial soils in the site's central portion (STP10, STP13 and STP40) were noted to contain organic inclusions at depths between 1.2m and 2.2m bgl. Low content of sub-angular to sub-rounded cobbles of sandstone have been recorded within a number of the exploratory hole locations. A number of the window sample boreholes and trial pits were terminated within the cohesive alluvial soils, at depths between 2.70m and 5.00m bgl. Possible granular alluvial soils were recorded within SBH03, SBH04 and locally within a window sample (SWS09) and a trial pit (STP43), within the former mill area to a maximum depth of 7.40m bgl. Trial pit STP43 and window sample borehole SWS09 were terminated due to collapse or refused within this material. The granular alluvial soils were recorded to comprise gravelly sand or silty gravel of sandstone. Low content of sub-angular to sub-rounded cobbles and boulders of sandstone were recorded within a number of the exploratory holes.
Completely Weathered Millstone Grit Formation (Residual Soils)	0.40m to 7.40m 0.70m to 1.50m where proven	Natural residual soils, were found below either the granular and / or the cohesive alluvial soils within the majority of the exploratory hole locations across the site. Locally to the north eastern portion of the site the alluvial soils were absent and as such the residual Millstone Grit Formation was found immediately below the made ground. The residual soils were recorded to comprise of both cohesive and granular soils. The cohesive residual soils were described as stiff to very stiff, locally firm sandy clay with gravel sized fragments of sandstone and mudstone. The granular residual soils typically comprised medium dense to very dense clayey sandy gravel of mudstone.
Millstone Grit Formation (Bedrock)	3.70m - 6.50m (NR)	Competent bedrock was encountered below the completely weathered Millstone Grit Formation within SBH04 and SWS03, within the south western and central portion of the former mill area, comprising very weak mudstone, to a maximum proven depth of 6.70m bgl.

Table 5.3 Strata Profile – NW of Former Mill (Area C)

Strata	Depth Range (Thickness Range)	Description and Comments
Made Ground	2.3m to >6.0m (3.2m where proven)	Made ground in this area was overlain by a layer of concrete and occasionally asphalt. This surface layer was in turn underlain by predominantly loose granular made ground, comprising a mix of gravelly sand, gravel or gravel and cobbles. The composition of the made ground was found to be of brick, sandstone, concrete, clinker and ash. A thin layer of cohesive made ground was noted in SWS16 only, found to be firm and soft low strength clay/ silt.
Alluvial Soils	3.2m (0.6m)	Found in SWS16 only. Alluvium was noted to be cohesive in nature of soft consistency and low strength.
Completely Weathered Millstone Grit Formation (Residual Soils)	3.8m (>2m)	Found in SWS16 only. Residual soil in this instance comprised a stiff high strength sandy gravelly clay.

Table 5.4 Strata Profile – Former Landfill (Area D)

Strata	Depth Range (Thickness Range)	Description and Comments
Made Ground / Made Ground Topsoil	Ground level (0.60m to 5.60m, where proven)	Made ground was encountered within all the exploratory holes within this area of the site, to depths typically between 2.70m and 5.60m bgl. Locally, to the central eastern portion of this area (near to the woodland area), the made ground was found to depths between 0.60m and 1.87m bgl. A number of the trial pits and window sample boreholes were terminated within the made ground soils and subsequently did not prove the full thickness of the fill materials. Within the western and central eastern parts of the former landfill area the made ground was noted to typically comprise a surface covering of reinforced concrete and locally asphalt hardstanding to depths typically between 0.14m and 0.40m bgl. Locally the concrete hardstanding in SWS20 was 0.83m thick. In addition, the reinforced concrete hardstanding with STP37 was unable to be broken, and as such the trial pit was terminated at 0.20m bgl. Locally within the northern portion of the former landfill area the made ground was noted to typically comprise a surface covering of grassed made ground topsoil to depths between 0.20m and 0.90m bgl. Made ground topsoil was described as soft sandy clay with gravel sized fragments of sandstone, brick and concrete. Within the majority of the exploratory holes, the made ground topsoil and hardstanding, where encountered, were found to be underlain by mixed granular and cohesive fill. The cohesive fill was recorded to typically comprise soft to firm, locally extremely soft, sandy clay with gravel of brick, concrete,

Strata	Depth Range (Thickness Range)	Description and Comments
		sandstone, limestone, mudstone and locally coal, ash, clinker, wood, plastic, metal, textiles, tiles, ceramics, charcoal and asbestos containing materials (ACMs). In addition, within SWS29 between 3.00 and 4.00m bgl a black gelatinous substance was recorded. A possible reworked alluvial soil was encountered within four exploratory hole locations (STP19, STP31, SWS27B and SWS28) within the northern portion of the former landfill area at depths between 0.40m and 5.00m bgl. The reworked alluvial soil comprised sandy clay with gravel of brick, sandstone, mudstone peat and/or organic debris and locally re-bar, wood and ash. SWS28 also identified decayed paper between 1.00m and 3.00m bgl. The granular fill was recorded to generally comprise loose to medium dense, locally very loose, sandy gravel / gravelly sand, sand & gravel, and gravel & cobbles of brick, concrete, sandstone, mudstone, metal, clinker and locally coal, charcoal, fabric, glass, plastic, metal, wood and limestone. Within approximately half the exploratory holes excavated / drilled within the former landfill area the granular fill was also noted to comprise large proportions of ash and clinker. This material was recorded at depths between ground level and 5.60m (maximum thickness 5.20m in SWS21). Both the cohesive and granular made ground were recorded to contain low to high content of sub-angular to sub-rounded cobbles and boulders of sandstone, brick and concrete. Frequent steel girders, copper pipe, steel sheets and concrete sub-structures / obstructions were encountered within the made ground soils.
Cohesive Alluvial Soils	0.60m to 5.60m (0.30m to 3.90m, where proven)	Cohesive alluvial soils were recorded underlying made ground soils across the majority of the former landfill area, generally comprising soft to firm (locally very soft or stiff) sandy clay / silt with gravel sized fragments of sandstone. Locally, STP27 and SWS23, were recorded to contain organic debris and peat at depths between 1.87m - 2.60m and 1.90m – 4.50m bgl. Low to high content of sub-angular to sub-rounded cobbles of sandstone have been recorded within a number of the exploratory hole locations. A number of the window sample boreholes and trial pits were terminated within the cohesive alluvial soils, at depths between 2.60m and 6.00m bgl.
Possible Granular Alluvial Soils	4.80m to 6.80m (1.60m to 4.00m)	Possible granular alluvial soils were recorded within the majority of the deep cable percussive boreholes, with the exception of SBH06 within the former landfill area, to a maximum depth of 10.80m bgl. SBH07 and SBH10 refused within this material at depths between 7.90m and 8.00m bgl.

Strata	Depth Range (Thickness Range)	Description and Comments
		The granular alluvial soils were recorded to comprise sandy gravel of sandstone and locally mudstone. Low content of sub-angular to sub-rounded cobbles and boulders of sandstone were recorded within a number of the exploratory holes.
Completely Weathered Millstone Grit Formation (Residual Soils)	3.60m to 10.80m (NR)	Natural residual soils, were found below either the granular and / or the cohesive alluvial soils within SBH06, SBH08, SBH09, SWS18, SWS19, SWS23, SWS42 and SWS43. The residual soils were recorded to comprise of both cohesive and granular soils. The residual soils were described as firm to very stiff sandy clay with gravel sized fragments of sandstone and mudstone. Within SBH06 granular residual soils were encountered at a depth of 4.80m bgl, comprising dense sandy gravel of mudstone. Locally, cobbles and boulders of sandstone were recorded within this strata.
Millstone Grit Formation (Bedrock)	7.90m (NR)	Competent bedrock was encountered below the alluvial soils within SBH06 only in this part of the site, i.e. within the eastern portion of the former landfill area, comprising very weak mudstone, to a maximum proven depth of 8.70m bgl.

NR - not recorded

Table 5.5 Strata Profile – North West (Area E)

Owing to the difference in topographical gradients the made ground part of this section has been divided into the upper and lower levels, forming the area near the road, and the area of the former effluent tanks /reservoir and mill race, respectively. There is a c. 4m difference between the upper and lower levels of this portion of the site.

For the purposes of clarity, the ground conditions encountered as part of the previous investigation completed by Sirius in June 2015 have also been included.

Strata	Depth Range (Thickness Range)	Description and Comments
Made Ground	Ground level (0.45m to 6.30m)	<u>Lower Level (approx. 99m AOD)</u> Made ground was encountered within all the exploratory hole locations to depths between 0.45m and 5.30m bgl. A number of the trial pits (TPA, TPB, TPC, TPE, TPG and TPH) and window sample boreholes (SWS33 and SWS38) did not prove the full thickness of the made ground soils within this area.

Strata	Depth Range (Thickness Range)	Description and Comments
		Typically made ground soils comprised cohesive fill, consisting of soft to firm, locally stiff, sandy clay/silty clay with gravel sized fragments of plastic, brick, concrete, ceramics, mudstone, sandstone, old clay pipes, wood, timber, coal, sandstone, limestone, tiles, flints, slate, metal, glass, ash, clinker and wires. In a number of the trial pits; namely TPA, TPB, TPC, TPE, TPF and TPH, low content of sub-rounded cobbles of brick, sandstone and concrete were recorded. Locally, within TPA and TPB, in the former reservoirs, a c. 0.10m thick band of soft slightly organic sandy silt, with reeds was recorded at depths between 2.50m and 2.80m bgl. A soft gravelly sandy silt/clay with organic and wood inclusions was encountered at depths of between 2.00m and 3.30m bgl in TPA, TPB, TPC, TPE, and SWS33 all located within the area of the former reservoirs. This material could represent basal sediment deposits and / or a reworked alluvial soil associated with the former reservoirs. Granular fill was also encountered within a number of the exploratory holes; including TPB, TPC, TPE, TPG, TPI, SWS34, SBH13, SBH15 and SBH16, at depths between ground level and 5.30m bgl. This material typically comprised clayey sands and gravel, gravelly silty sand, gravelly sand and sandy gravel. The gravel fraction included sandstone, mudstone, and locally flint, ash, brick, concrete, ceramic, tiles, glass, plastic and coal. Locally, within BH15 and SBH16, within the northern portion, forming the former effluent tanks, the granular fill was also recorded to comprise a low content of angular to sub-angular cobbles / boulders of sandstone and concrete were recorded. A number of the trial pits (TPA, TPG and TPH) and window sample boreholes (SWS33 and SWS38) were terminated within the made ground soils, on presumed concrete obstructions associated with the former reservoirs and effluent tanks etc. at depths between 1.60m and 4.10m. <u>Upper Level (Approx. 105m AOD)</u> Made ground was encountered within each of the exploratory hole locations to depths between 4.80m and 6.90m bgl The made ground typically comprised a surface covering of asphalt hardstanding, between 0.04m and 0.15m thick. The surface covering of hardstand, was typically found to be underlain by mixed granular fill. The granular fill was generally described as very loose to loose locally clayey sandy gravel of brick, concrete and sandstone, to depths between 0.80m and 5.90m. Locally, within SWS35 and SWS41, the granular fill also comprised a c. 0.60m and 1.80m thick band of loose clayey sandy gravel of ash, brick and concrete to depths between 0.95m and 4.80m.

Strata	Depth Range (Thickness Range)	Description and Comments
		A cohesive fill was locally encountered within SWS35 below the granular fill, to a depth of 4.80m bgl comprising very soft to soft sandy clay with gravel sized fragments of sandstone and concrete.
Cohesive Alluvial Soils	0.45m – 6.30m (0.90m to 2.60m, where proven)	Cohesive alluvial soils were recorded within a number of the exploratory holes (namely TPF TPI, SWS34, SWS41 and SBH14) across this area of the site, comprising very soft to firm sandy clay with gravel sized fragments of sandstone and mudstone. Locally within SWS34 gravel sized inclusions of organic debris were recorded at depths between 2.20m and 4.80m bgl. Where exploratory positions fully penetrated made ground, cohesive alluvial soils were noted to be absent within TPD, SWS35, SBH13, SBH15 and SBH16.
Possible Granular Alluvial Soils	1.85m – 5.30m (0.70m to 2.30m, where proven)	Possible granular alluvial soils were recorded within a number of the exploratory holes (TPD, TPF, SWS34, SBH13, SBH15 and SBH16) below the cohesive soils where present, or immediately below the made ground soils. The granular soils comprised medium dense to dense slightly clayey sandy / silty gravel of sub-angular to sub-rounded sandstone. Low content of sub-angular to sub- rounded cobbles and boulders were recorded within TPD, TPF and SBH15. The granular alluvial soils were absent within TPI and SWS35.
Completely Weathered Millstone Grit Formation (Residual Soils)	4.80m – 7.70m (NR)	Natural residual soils, were found below either the made ground soils and / or the granular / cohesive alluvial soils, within SWS35, SWS41 and SBH14. The residual soils were described as stiff to very stiff sandy clay with gravel sized fragments of sandstone and mudstone. Locally within SBH14 (upper level), the upper residual soils, between 7.70m and 9.80mbgl were described as soft sandy gravelly clay. This is considered representative of groundwater softening.
Millstone Grit Formation (Bedrock)	5.00m – 7.60m (NR)	Competent bedrock was encountered below the granular alluvial soils within SBH13, SBH15 and SBH16 (lower level), comprising very weak mudstone at depths between 5.00m and 7.60m bgl, and proven to a maximum depth of 8.00m bgl.

NR - not recorded

Table 5.6 Strata Profile – South West (Area F)

Owing to the difference in topographical gradients the made ground part of this section has been divided into the upper and lower levels, forming the northern area (nearest the entrance to the site), and the southern area (nearest the River Don), respectively. There is a c. 5m difference between the upper and lower levels of this portion of the site.

Strata	Depth Range (Thickness Range)	Description and Comments
Made Ground	Ground level (2.80m to 4.10m, where proven)	<u>Lower Level (Approx. 95m AOD level)</u> Made ground was encountered within each of the exploratory hole locations to depths between 2.80m (STP49) and 4.10m bgl (SBH11). A number of the exploratory hole locations, namely SWS31, SWS31A-D SWS30, SWS30A, and STP42 have not proven the full depth of the made ground, owing to localised collapses and / or obstructions. The made ground comprised a surface covering of reinforced concrete hardstanding, between 0.15m and 0.25m thick. A number of exploratory hole locations, namely SWS31 and SWS31A-D were terminated within the reinforced concrete hardstanding at depths between 0.13m and 0.25m. The surface covering of hardstand, was typically found to be underlain by mixed granular and / or cohesive fill. The granular fill was generally described as silty sandy gravel. The gravel fraction comprised fragments of brick, concrete, sandstone and locally ash. The cohesive fill comprised soft to firm sandy clay with gravel and locally cobbles and boulders of sandstone, brick, concrete and locally coal and mudstone. <u>Upper Level (Approx. 100m AOD level)</u> Locally, within STP34, the made ground comprised a surface covering of reinforced concrete hardstanding c. 0.20m thick. This was in-turn underlain by a thin c. 0.25m thick of granular made ground, comprising sandy gravel of brick and concrete. A black silty sand and gravel of ash and clinker with brick and concrete was recorded at depths between 0.45m and >3.40m bgl within this location. Elsewhere trial pits STP35 and STP36, and boreholes SBH12 and SBH12A, were drilled / excavated within the demolition fill that forms a slope / mound between the upper and lower levels of this portion of the site. The demolition fill comprised sandy gravel and cobbles of brick, concrete, metal and wood to a maximum proven depth of 4.10m bgl in SBH12. SBH12 was terminated in the demolition fill at 4.20m on concrete, which is believed to form the concrete hardstanding seen within SWS30, SWS30A, STP42 and STP49 nearest the River Don. Whilst SBH12A was terminated in the demolition fill at 0.80m bgl. Locally within SWS30A and STP49 possible reworked alluvial soils were recorded to a maximum proven depth of 2.80m bgl, comprising a soft very sandy locally gravelly clay. All holes were terminated within the made ground soils. Frequent brick, concrete and stone sub-structures / obstructions were encountered within the made ground soils in both the upper and lower levels.

Strata	Depth Range (Thickness Range)	Description and Comments
Cohesive Alluvial Soils	2.80m bgl (NR)	Cohesive alluvial soils were recorded in the lower level plateau, within STP49, to a maximum depth of 3.20m bgl, where the pit was terminated due to the side collapsing and groundwater ingress. The cohesive alluvial soils were recorded to comprise of very soft slightly sandy slightly gravelly clay / silt.
Possible Granular Alluvial Soils	4.10m bgl (NR)	Possible granular alluvial soils were recorded in the lower level plateau within the SBH11, to a maximum depth of 4.60m bgl, where refusal was met on a presumed boulder and / or cobble. The granular alluvial soils were recorded to comprise sandy gravel of sandstone.

NR - not recorded

5.2. Material Properties

Results of geotechnical analysis and in-situ testing have been used, where applicable, from the previous investigation undertaken by WSP. These have been assessed alongside the more recent geotechnical analysis and in-situ testing obtained as part of both aforementioned Sirius' intrusive investigations.

For the purposes of clarity, the material properties for each individual strata type have been assessed for the entire site.

Made Ground/ Made Ground Topsoil

Forty Standard Penetration Tests (SPTs) undertaken in the cohesive made ground across the site, recorded 'N' values of between 0 and 50 (mean and median values of 11 and 7), indicative of material ranging from extremely low strength to high strength cohesive material.

Atterberg limit determinations undertaken on four samples of cohesive made ground revealed liquid limits of between 30% and 53%, with plastic limits of between 20% and 25% and plasticity indices of between 8% and 28%. This data indicates the cohesive made ground to be highly variable material of low to high plasticity. Calculation of the modified plasticity index in two samples (Ref. SBH16 and BH204) indicates that these samples have a generally low volume change potential. SWS35 and SBH13 both returned modified plasticity indices below <10%, thereby indicating that the samples are non-shrinkable clays.

The Consistency Indices (Ic) of the samples tested indicates Ic values of between 0.36 and 2.00, indicative of soft and very stiff soils

Fifteen hand shear vanes undertaken within the cohesive made ground located across the site, identified shear strengths of between 10kPa and 52kPa, with mean and median values both recorded at 26kPa, indicative of very low, to medium strength soils. Based on the SPT 'N' values and plasticity indices obtained from within the cohesive soils across the site an indicative undrained shear strength has been calculated of between 0kN/m^2 and 300kN/m^2 (mean and median values of 67kN/m^2 and 42kN/m^2), indicating extremely low to very high strength soils.

Eighty seven SPTs undertaken within the granular made ground across the site recorded uncorrected 'N' values of between 1 and 37 (mean and median values of 10 and 7, respectively), indicating soils of variable density ranging from very loose to dense. The higher 'N' values are considered attributable to the presence of cobbles / boulders within the made ground.

Twelve SPT 'N' values exceeding 50 were recorded within the granular and cohesive made ground indicating the presence of impenetrable obstructions and / or cobbles / boulders within the composition of these materials.

Superficial Soils

Alluvial Soils

Thirty eight SPTs undertaken within cohesive alluvial soils returned 'N' values ranging between 3 and 48. Mean and median 'N' values were calculated as 13 and 9, respectively.

Atterberg limit determinations undertaken on eighteen samples of cohesive alluvial soils revealed liquid limits of between 25% and 56%, plastic limits of between 14% and 28% and plasticity indices of between 10% and 28%. This data indicates the cohesive material to be of low to high plasticity. Calculation of the modified plasticity index indicates these samples to have a low to medium volume change potential. SBH03 returned a modified plasticity index below <10%, thereby indicating that the sample is a non-shrinkable clay.

The Consistency Indices (Ic) of the samples tested indicates highly variable Ic values of between 0 and 1.17, indicative of very soft and very stiff soils.

Five unconsolidated undrained triaxial tests were undertaken on five undisturbed samples of the cohesive alluvial soils, obtained from SBH01, SBH02, SBH05, SBH08 and SBH09 at depths of between 2.20m and 4.95m bgl. The samples recorded undrained shear strengths of between 15kN/m^2 to 27kN/m^2, indicative of very low, to low strength cohesive soils.

The alluvial soils are anticipated to be normally consolidated. Three one dimensional consolidation tests were undertaken on samples of the cohesive alluvial soils obtained from SBH02, SBH05 and SBH09 at depths of between 2.20m and 4.95m bgl. The sample recorded moisture contents of between 14% and 28%, bulk densities of between 2.05Mg/m^3 and 2.31Mg/m^3 and dry density of 1.61Mg/m^3 and 2.02Mg/ m^3. The results indicate a coefficient of volume compressibility Mv for the samples tested to be between 0.140MN/m^2 and 0.344MN/m^2 for the pressure range of overburden pressure plus 100kPa.

Indicative undrained shear strengths of cohesive soils can be derived by applying a correlation to SPT 'N' values according to the material's plasticity, after Stroud (1975)[1]. Based on an average plasticity index of 18% for the cohesive soils a correlation factor of 5 can be derived. Using Stroud's correlation the SPT 'N' values indicates undrained shear strengths of between 20kN/m^2 and 240kN/m^2 indicating very low to very high strength soils.

Thirty hand shear vanes undertaken within the cohesive alluvial soils, identified shear strengths of between 10kPa and 55kPa, with mean and median values is 27kPa and 25kPa, indicative of low strength soils.

Three CBR tests were undertaken in the laboratory on three compacted bulk sample of cohesive alluvial soils. The results of the laboratory CBR testing is summarised within Table 5.7.

Table 5.7 Summary of Laboratory CBR Tests (Cohesive Alluvial Soils)

Sample ID	Depth (m bgl)	Strata Description	Moisture Content (%)	Bulk Density (Mg/m^3)	Dry Density (Mg/m^3)	CBR value – Top (%)	CBR value – Bottom (%)
STP01	0.60 – 0.80	Cohesive Alluvial Soils	28	1.93	1.51	1.1	1.1
SBH03	3.20 – 3.70	Cohesive Alluvial Soils	25	1.96	1.57	0.2	0.2
SBH06	3.70 – 4.20	Cohesive Alluvial Soils	37	1.81	1.32	0.1	0.1

Nine SPTs undertaken within the granular alluvial soils across the site recorded uncorrected 'N' values of between 20 and 47 (mean and median values of 30 and 31, respectively), indicating soils of densities ranging from medium dense to dense.

[1] Stroud, M. A. The standard penetration test in insensitive clays and soft rocks, *Proceedings of the European Symposium on Penetration Testing,* 2, 367 – 375 (1975)

Seventeen SPT 'N' values exceeding 50 were recorded within the granular and cohesive alluvial soils indicating the presence of impenetrable obstructions and / or cobbles / boulders within the composition of these materials.

Millstone Grit Formation (Residual Soils)

Forty SPTs undertaken within cohesive Millstone Grit Formation returned 'N' values ranging between 4 and 50. Mean and median 'N' values were calculated as 23 and 22, respectively.

Atterberg limit determinations undertaken on nine samples of cohesive completely weathered Millstone Grit Formation revealed liquid limits of between 27% and 40%, plastic limits of between 16% and 23% and plasticity indices of between 10% and 20%. This data indicates the cohesive material to be of low to intermediate plasticity. Calculation of the modified plasticity index indicates these samples to have a low volume change potential. STP45 returned a modified plasticity index below <10%, thereby indicating that the sample is a non-shrinkable clay.

The Consistency Indices (Ic) of the samples tested indicates Ic values of between 0.31 and 1.21, indicative of very soft and very stiff soils.

Indicative undrained shear strengths of cohesive soils can be derived by applying a correlation to SPT 'N' values according to the material's plasticity, after Stroud (1975)[2]. Based on an average plasticity index of 15% for the cohesive soils a correlation factor of 6 can be derived. Using Stroud's correlation the SPT 'N' values indicates undrained shear strengths of between 24kN/m^2 and 300kN/m^2 indicating low to very high strength soils.

Five hand shear vanes undertaken within the cohesive Millstone Grit Formation, identified shear strengths of between 50kPa and 120kPa, with mean and median values is 94kPa and 120kPa, indicative of medium to high strength soils.

One CBR test was undertaken in the laboratory on a compacted bulk sample of cohesive Millstone Grit Formation which returned a moisture content of 15%, a bulk density 2.22Mg/m^3, dry density 1.94Mg/m^3 and a CBR value top of 0.8% and a CBR bottom value of 0.7%.

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[2] Stroud, M. A. The standard penetration test in insensitive clays and soft rocks, *Proceedings of the European Symposium on Penetration Testing,* 2, 367 – 375 (1975)

Seventeen SPTs undertaken within the granular Millstone Grit Formation across the site recorded uncorrected 'N' values of between 10 and 39 (mean and median values of 24 and 23, respectively), indicating soils of densities ranging from medium dense to dense soils.

Twenty three SPT 'N' values exceeding 50 were recorded within the granular and cohesive Millstone Grit Formation indicating the presence of cobbles / boulders within the composition of these materials.

SPTs undertaken in the bedrock recorded uncorrected 'N' values of between 23 and 50 for 230mm penetration and extrapolated SPT 'N' values of 300 to 652, indicative of medium dense soil to very weak rock.

5.3. Groundwater

Tables 5.8 and 5.9 below summarise the water strikes and the strata within which perched water / groundwater was encountered in each of the six areas (as shown on Drawing No. C6485D/02, in Appendix A) during both phases of site investigation.

June 2015 Site Investigation

Groundwater was encountered in seven of the shallow exploratory holes (trial pits) as water strikes or seepages within the made ground, and locally the completely weathered Millstone Grit Formation / possible granular alluvial soils at depths of between 1.50m and 4.00m bgl.

Table 5.8 Groundwater Strikes (June 2015)

Exploratory Hole No	Water Strike (m bgl)	Standing Level after 20 min (m bgl)	Material Type (comments)
North West Area E – Former Effluent Tanks / Reservoirs / Mill Race			
TPA	2.20	NA	Cohesive Made Ground (hydrocarbon sheen noted to groundwater).
TPB	3.30	NA	Cohesive Made Ground
TPC	4.00	NA	Granular Made Ground
TPE	2.70	NA	Cohesive Made Ground
	3.50		
TPF	2.40	NA	Possible Granular Alluvium
TPG	1.95	NA	Granular Made Ground
TPH	1.50	NA	Cohesive Made Ground

NA – Non Applicable

Trial pits TPD and TPI were both recorded to be 'dry' at the time of the June intrusive investigation.

The majority of the groundwater levels recorded, with the exception of TPF, are considered representative of a perched water table.

November 2015 to January 2016 Site Investigation

For the purposes of this report the groundwater strikes have been recorded within Table 5.8 based on the five distinct areas of the site, as seen on Drawing No. C6485D/02, within Appendix A.

Table 5.9 Groundwater Strikes (November 2015- January 2016)

Exploratory Hole No	Water Strike (m bgl)	Standing Level after 20 min (m bgl)	Material Type (comments)
Former Landfill (Area D)			
SBH06	3.10	3.00	Cohesive Made Ground (Perched water table)
	8.30	4.50	Mudstone Millstone Grit Formation
SBH07	4.10	3.50	Granular Made Ground (Perched water table)
SBH09	8.60	5.00	Cohesive Completely Weathered Millstone Grit Formation
STP19	0.60	NA	Cohesive Made Ground (Perched water table)
STP20	0.80	NA	Granular Made Ground (Perched water table)
STP21	2.30	NA	Cohesive Alluvium
STP26	3.00	NA	Cohesive Made Ground (Perched water table)
STP27	1.80	NA	Granular Made Ground (Perched water table)
STP28	0.30	NA	Cohesive Made Ground (Perched water table)
STP31	2.00	1.80	Cohesive Made Ground (Perched water table)
STP32	3.20	NA	Cohesive Made Ground (Perched water table)
SWS21	4.50	NA	Granular Made Ground (Perched water table – possible sheen to water)
SWS23	4.20	NA	Cohesive Alluvium
SWS28	1.40	NA	Cohesive Made Ground (Possible reworked Alluvium – Perched water table)
SWS29	2.00	NA	Granular Made Ground (Perched water table)
Former Mill Area (A, B and C)			
SBH01	4.20	3.10	Granular Completely Weathered Millstone Grit Formation
	6.80	4.00	Granular Completely Weathered Millstone Grit
SBH02	6.10	5.10	Cohesive Alluvium
SBH03	3.00*	NA	Cohesive Alluvium
	8.10	5.00	Cohesive Completely Weathered Millstone Grit Formation
SBH04	4.00	3.00	Possible Granular Alluvium

Exploratory Hole No	Water Strike (m bgl)	Standing Level after 20 min (m bgl)	Material Type (comments)
	6.30	4.10	Cohesive Completely Weathered Millstone Grit Formation
SBH05	0.40	NA	Granular Made Ground (Perched water table)
STP04	2.30	NA	Cohesive Millstone Grit Formation
STP05	2.30	NA	Cohesive Millstone Grit Formation
STP09	2.30	NA	Cohesive Alluvium
STP10	2.40	NA	Cohesive Alluvium
STP40	3.15	NA	Cohesive Alluvium
STP43	2.60	NA	Granular Alluvium
SWS02	1.00	NA	Cohesive Alluvium
SWS06	4.80	NA	Cohesive Completely Weathered Millstone Grit Formation
SWS09	2.50	NA	Possible Granular Alluvium
SWS10	3.50	NA	Cohesive Alluvium
SWS16	3.60	NA	Cohesive Alluvium
SWS17	0.50	NA	Granular Made Ground (Perched water table)
South West (Area F)			
SBH11	4.00	3.50	Granular Made Ground (Perched water table)
SBH12	4.10	4.00	Cohesive Made Ground (Perched water table)
STP49	2.70	NA	Cohesive Made Ground (Possible reworked Alluvium – Perched water table)
North West (Area E)			
SBH13	2.70	1.50	Cohesive Made Ground (Perched water table)
	7.90	4.00	Mudstone Millstone Grit Formation
SBH14	11.00	8.00	Cohesive Completely Weathered Millstone Grit Formation
SBH15	4.30	4.00	Possible Granular Alluvium
SBH16	2.90	2.50	Cohesive Made Ground (Perched water table)
	5.00	3.00	Mudstone Millstone Grit Formation
SWS33	4.50	NA	Cohesive Made Ground (Possible reworked Alluvium – Perched water table)
SWS38	3.50	NA	Cohesive Made Ground (Perched water table)

NA – Non Applicable; *Note groundwater recorded at start on shift, by driller.

Subsequent groundwater monitoring, undertaken by Sirius, of the standpipes installed within the selected cable percussive and window sample boreholes has revealed perched water / groundwater, where present, to be standing at depths of between 0.15m and 6.70m bgl.

Based on the groundwater levels recorded and response zones of the wells it has not been possible to confirm the groundwater flow direction, however, at this stage, it is assumed that the groundwater flow would follow the natural topography of the site and the River Don, and as such be in a south / south easterly direction.

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

5.4. Obstructions / Remnant Structures

Based on the historical information available for the site and the previous intrusive investigations undertaken for the site it is anticipated that extensive former structures including foundations, underground services etc. will exist below the site.

Tables 5.10 and 5.11 below summarise the location, depths and any details of obstructions / remnant structures / services etc. which were encountered during the investigation works by Sirius.

June 2015 Site Investigation

Table 5.10 below provides a summary of where remnant sub-structures have been identified within the north western area E (i.e. former effluent tanks / reservoir / mill race), as recorded in June 2015.

Table 5.10 Obstructions / Remnant Structures (June 2015)

Exploratory Hole Ref.	Depth (m bgl)	Comment
TPA	4.10	Trial pit ceased owing to concrete structure at base (possible base of reservoir).
TPC	0.20 – 1.00	Concrete wall/structure with steel beams recorded to western flank of pit. Possible wall of mill race or reservoir.
TPE	1.20 – 2.20	Concrete wall/structure with steel beams recorded to western flank of pit. Possible wall of mill race or reservoir.
TPG	3.10	Trial pit ceased owing to concrete structure at base (possible base of effluent tank).
TPH	1.60	Trial pit ceased owing to concrete structure at base (possible base of effluent tank).

In addition, a further trial pit, TPI, was excavated to the south eastern flank along the perimeter of an existing presumed retaining wall associated with the site, nearby to the River Don. The trial pit did not encounter any sub-structure below ground surface.

November 2015 to January 2016 Site Investigation

Obstructions / remnant structures encountered as part of the most recent phase of investigation are recorded within Table 5.11 below.

Table 5.11 Obstructions / Remnant Structures (2015-2016)

Exploratory Hole Ref.	Depth (m bgl)	Comment
Former Landfill (Area D)		
STP22	0.70	Vertical steel pipe in north east corner of trial pit.
STP24	0.55	Copper pipe approximately 40mm diameter (possible service)
STP27	0.80	Steel girder recorded in granular made ground.
STP28	2.30	Steel girder recorded in cohesive made ground.
	2.60	Large concrete boulder approximately 800mm diameter recorded in cohesive made ground.
STP30	1.30 - 2.40	Single large steel sheet at approximately 45 degree angle recorded in cohesive made ground.
STP32	0.30	Bituminous roofing material encountered in cohesive made ground.
	1.30	Reinforced concrete in northern part of trial pit. Recorded in cohesive made ground.
STP33	2.00	Low content of angular boulders of sandstone and concrete up to 900mm diameter. Recorded in cohesive made ground.
STP37	0.20	Trial pit ceased owing to heavily reinforced concrete. Unable to break with hydraulic breaker.
Former Mill Area (A, B and C)		
STP08	0.80	Trial pit ceased owing to concrete obstruction – possible service.
STP12	0.70	Trial pit ceased owing to concrete obstruction – possible service.
STP14	1.20 - 1.90	Trial pit ceased owing to capped steel pipe approximately 150mm diameter – possible service.
STP18	0.20	Trial pit ceased owing to heavily reinforced concrete. Unable to break with hydraulic breaker.
STP23	0.10	Trial pit ceased owing to heavily reinforced concrete. Unable to break with hydraulic breaker.
SWS08	0.30	Window sample ceased owing to heavily reinforced concrete. Unable to core concrete.
SWS13	0.80	Window sample refused on presumed concrete cobble, in granular made ground.
SWS15 & SWS15A	1.00	Window samples refused on presumed concrete cobble, in granular made ground.
SWS45	0.30	Window sample ceased owing to heavily reinforced concrete.

Exploratory Hole Ref.	Depth (m bgl)	Comment
Former Landfill (Area D)		
		Unable to core concrete.
South West (Area F)		
SBH12	4.30	Borehole refused owing to concrete obstruction - presumed floor slab of former buildings.
SBH12A	0.80	Borehole refused on presumed concrete obstruction, within granular made ground – demolition fill.
STP34	0.40 beyond 2.40m	Stone wall recorded to western face of trial pit.
STP35	From 1.00	Brick wall recorded to southern face of trial pit.
STP42	1.20 - 1.80	Concrete recorded within western face of wall.
STP49	0.25 - 0.53	Brick wall recorded within western face of trial pit.
SWS31, SWS31A-D	At depths between 0.13 - 0.25	Window sample ceased owing to heavily reinforced concrete. Unable to core concrete.
North West (Area E)		
SWS33	5.00	Window sample ceased within cohesive made ground. Possible on concrete obstruction – possible base of reservoir.
SWS38	4.00	Window sample ceased within cohesive made ground. Possible on concrete obstruction – possible base of ‘unknown’ structure.

Other potential obstructions include cobbles and boulders recorded within natural cohesive and granular soils encountered across the site. In addition, a number of large trees roots/trunks were recorded within the natural alluvial soils. These were generally noted within the soils underlying the mill building, toward the River Don.

6. RESULTS OF SETTLEMENT ANALYSIS

It is considered that there are possibly three settlement mechanisms that could affect the surface stability of the ground following completion of the development. There are:

1) Collapse Compression

2) Creep Settlement

3) Consolidation Settlement

With respect to settlement mechanism No.1, such mechanisms can occur as a result of a rise in groundwater level following placement of recent fill materials. Such materials may also have been inadequately compacted. It is however, considered that this settlement mechanism poses a relatively low risk to the proposed development. This assessment is based on the following:

A) Final site levels have been established for a number of decades, any settlement that may have taken place via this mechanism, is likely to have had time to complete/ manifest itself.

B) Being located within a valley base (River Don), the site is highly likely to have been subject to several temporary rises in groundwater via numerous flooding events in that time,

C) Equilibrium groundwater levels will have had time to establish.

D) Albeit this can be area specific, a significant proportion of made ground is noted to be granular in nature. Collapse compression has known to have one of its greatest effects on rises in groundwater within cohesive soils placed/ “compacted” dry of optimum.

E) An assumption that any rise in site levels will comprise materials that have been adequately classified/ sorted, compacted and in turn validated, in accordance with a suitably robust engineering earthworks specification.

With respect to settlement mechanism No.2, this could feasibly occur beyond completion of the development. However, in light of the fill thickness in parts, fill types, the time fill materials have been placed on this site and, the past end use for materials, for example support of the main mill/ ancillary mill building floors and hardstand used for truck movements for a number of decades, this settlement mechanism is considered to pose a low risk in parts of the site, in particular Areas A, B1, B2, C and F. However, a moderate risk to Area D and high risk to Area E could be anticipated.

With respect to the moderate risk rating for Area D, the made ground within the landfill contains a mix of both granular and cohesive fills, of variable composition. There is some evidence to indicate the landfill was commenced, according to historical Ordnance Survey (OS) maps, sometime between 1970 and 1983 and by aerial photographs as early as pre 1969. Deposition of materials is shown on OS maps to be well underway by 1983.

The high risk rating for Area E is based on much of the made ground within the former reservoirs/ tanks and mill race being placed relatively recently, i.e. around 2014. The June 2015 and 2016 Sirius investigations encountered predominantly soft/ soft and firm consistency, low strength cohesive fill within the former reservoirs. In addition, it is not known, at this point in time, if this material was classified and compacted in a controlled manner. The low strength and consistency of the cohesive fills suggest this was not the case.

Creep settlement assessment is difficult to predict accurately, in part, where this issue manifests itself it can be attributed to the unpredictable nature of fill materials involved. Creep settlement has been researched via case history evidence. Using BRE 427 Part 1 which relies on case history performance of fills, a crude estimate of creep settlement can be estimated. This is based on a percentage reduction in stratum height over a log cycle of time. At this stage, it could be assumed fill within Area D is within log cycle 10 to 100 years and Area E 1 to 10 years.

Based on values within Table 1 of BRE 427, a compression rate parameter (α) of 3 to 5 has been assumed for cohesive fill within Area E and 5 for the landfill materials within Area D.

Lower rates of α are expected for fill types within other parts of the site. There will also be instances where creep settlement will not be relevant. This is particularly applicable to Area A, where made ground is thin and rises in site levels are relatively modest.

Calculations thus indicate that within Area D, creep settlements in the order of 100mm (based on SWS28 which has a worst case 3.8m of cohesive fill, containing organic elements), could occur within the next 70 years (i.e. the balance of the 10 to 100 log cycle since cessation of in-filling, which at this point is assumed to be in the 1980s).

Similarly, within Area E, ground conditions encountered within SWS33 (thought to have been sunk within a backfilled reservoir) has been used to assess creep settlement that could occur over the reminder of the 1 to 10 year log cycle of time. This is estimated to be in the order of 140mm. A slightly larger amount of settlement in the region 200mm is estimated to occur within this material in the following, 10 to 100 year log cycle of time.

Clearly settlements can be reduced based on the thickness of untreated made ground that may remain beneath a predetermined “turnover” depth of made ground.

A sensitivity analysis to estimate the magnitude of creep settlement from 2 years (i.e. time of writing this report) to 60 years following placement, with variable thicknesses of untreated made ground remaining within the former reservoirs and a baseline/ modelled thickness of 5m of infill, are given in Table 6.1 below.

Table 6.1 Magnitude of Predicted Creep Settlement

Thickness of untreated backfill above former reservoir base(m)	Creep settlement 2 to 60 years following placement (mm)
1	75
2	150
3	225
4	295
5	370

Settlement mechanism No.3, consolidation settlement, has been subject to the greatest attention. This is based on not only the presence of cohesive made ground, but also cohesive alluvium which underlies much of the site and is organic in parts. Consolidation settlement has therefore been based on the magnitude of rise in proposed site level (increase in applied stress), the sensitivity of the structure proposed (i.e. adoptable highways, external areas to residential dwellings and public open space based on the outline architectural layout) and the ground conditions at each exploratory location. This has led to a sensitivity analysis of possible consolidation settlement throughout the site. The above approach has been the predominant criterion for zoning the site into Areas A to F.

Reference can be made to indicative rockhead contours, in addition to suggestive alluvial soils and made ground thickness plots shown as Drawings C6485D RevA/03, 04 and 05 respectively.

Table 6.2 overleaf gives estimates of possible primary consolidation settlements within alluvium for each area. The calculations below assume settlement within made ground will be negligible based on the following assumptions:

A) Where Made Ground is thin i.e. <1m within residential plot external areas and <2m beneath adoptable highways, this will facilitate complete removal, classification and if suitable, compaction to an approved engineering specification to final site level.

B) Made ground below 1m/ 2m which is not “turned over” is exclusively granular in nature

C) Cohesive made ground >1m depth deemed unsuitable shall be removed, stabilised, adequately compacted, or replaced with a suitable fill.

Table 6.2 Estimates of Primary Consolidation Settlement

Area	Estimate of Primary Consolidation Settlement within alluvium (mm)	Maximum Increase in Site Level (at chosen point of calculation) (m)	Record used for Calculation	Comments
A	25 to 30	1.39	SWS11	Made ground is <1m thick in this area, with the exception of SBH01, which comprises 2m of granular fill.
B1	65	1.5	SBH02	Where the full thickness of made ground is known in this area, this varies from 0.35m to 3.6m. Whole sale turnover of made ground to 2m below ground level could be advised. Areas where made ground is observed to be >2m, this is observed to be granular in nature.
B2	60	1.6	SBH03	Where the full thickness of made ground is known in this area, this varies from 1.2m to 2.7m. Whole sale turnover of made ground up to 2.0m below ground level could be advised. Areas where made ground is observed to be >2m, this is observed to be predominantly granular in nature, with exception of STP11. **Alluvium is noted to be organic in this area**

C	N/A	-1	N/A	Made Ground is predominantly granular in this Area. Generally, proposed levels are to be reduced in this area, leading to no increase in applied stress to alluvium
D	25	1	SWS42	Extensive thicknesses of made ground within the landfill (>5.5m). However very low and limited extent of rise in site levels proposed. It is proposed in many parts of this area to reduce final site level.
E	21 to 25	1.15	SBH13	Part of the embankment area is proposed to be reduced in level, leaving this area effectively surcharged. In view of the magnitude of possible creep settlements within the reservoir/ pond/ mill race zone it is recommended fill beneath adoptable highways is subject to treatment. (i.e. Excavation and compaction, in situ soil mixing, ex situ lime or cement) stabilisation etc.). It is likely highways will require full depth treatment in order to gain Section 38 approval. Areas outwith adoptable highways could be subject to partial treatment, to mitigate levels of creep settlement to an acceptable amount. For example the optimum removal could comprise leaving 2m of untreated infill within the base of the reservoirs limiting creep settlement to 150mm over the

				expected lifetime of the development.
F	10 to 15	1	STPC01	Where the full thickness of made ground is known in this area, this varies from 0.5m to 4.1m. Made Ground is often noted to be in excess of 2.0m thick, though is predominantly granular in nature or stiff consistency clay. Some areas have soft consistency cohesive made ground >2.5m beneath proposed adoptable highways roads (i.e. STP42), which could require full depth treatment of made ground, comprising excavation classification, compaction supplemented by stabilisation with lime/ cement. Much alluvium is noted to be granular or stiff consistency clay in this area. Materials described as alluvium to the west could be colluvial deposits.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. General

This settlement report has been performed for land at Oughtibridge Mill, Oughtibridge, Sheffield.

This report is based on information provided by CEG's consultancy team; including Sirius. Settlement evaluation assumes that proposed ground levels will consider minimum flood levels, with congnisance of additional build up for highway/plot construction and cover soils in gardens.

Generalised foundation recommendations for residential dwellings are given within Sirius Geoenvironmental Appraisal Report C6485A Rev A, dated March 2016. Drawing No. C6485D/7 in Appendix A provides a foundation zoning plan based on soil conditions, post enabling. This settlement report discusses settlement within highways, external areas and public open space.

7.2. Ground Settlement

Areas A, B1, C and F

It is clear from the assessment above, that estimates of settlement within Areas A, B1, C and F could be limited to a range <10mm (Area C) to 65mm Area (B1). It is reasonably expected that such settlements could be designed/ accommodated within external areas, public open space and adoptable highways.

Notwithstanding the above, assessment of settlement has assumed that made ground is subject to a 1m minimum "turnover" (i.e. excavation, subsequent classification of arisings and if suitable for compaction, placed and validated in accordance with an engineering specification), in areas of residential external areas and public open space. A 2m "turnover" beneath adoptable highways is proposed. In the event made ground is deeper than the turnover depth, but is granular in nature, placement of a geogrid could be proposed at the 2m depth beneath adoptable highways, or below the invert level of proposed drainage alignments whichever is the deepest.

Made ground encountered at depths in excess of turnover depth can remain untreated if proven to be predominantly granular in nature. However, cohesive made ground, which is often soft/ low strength in nature, at depths in excess of 2m was noted locally. In these areas, it would be prudent to consider full depth treatment, which could comprise and not limited to the following:

A) complete excavation classification and if suitable compaction and validation in accordance with an approved earthworks specification,

B) in situ or ex situ soil stabilisation using lime and or cement which would be subject to relevant soil testing/ site trials

Area B2

This area has been segregated from area B1, owing to the presence of organic alluvium beneath the made ground. Estimates of primary consolidation settlement within the alluvium are based on engineering judgement at this stage. This area may well give rise to greater settlements, dependent on which parameters are chosen for calculation. As such, should reassessment of predicted settlements exceed those within the areas grouped above, there may be a need to either accommodate this in design, or consideration could be given to accelerate consolidation settlements within the alluvium, for example via surcharging.

Use of surcharging, could limit the magnitude of primary consolidation settlement within the alluvium following construction of the development. At this stage it is estimated that placement of fill to 1m above assumed site levels could surcharge the ground and be timed to leave a residual consolidation settlement, after surcharging of for example 25mm. Using available data to assess likely rates of settlement, it is estimated that placement of fill to 1m above assumed site levels (and subsequently removed on completion of surcharging) could leave residual primary consolidation settlements of 25mm in a period of approximately 1 to 2 months. This is assuming no additional drainage is introduced to the cohesive alluvium within surcharge zone and drainage of excess porewater pressure also occurs within underlying granular alluvium and Millstone Grit Formation rock.

Area D

This area comprises the landfill. Despite the significant thickness of fill within the landfill, in light of the low increases in proposed site level, which are generally of limited extent, the effects of proposed development levels on alluvial consolidation settlements in this area are estimated to be relatively low. This is based on the assumption the alluvium has already been subject to significant surcharging by the existing fill.

However, creep settlement is still a major settlement mechanism in this area, which even though a crude assessment of settlement has been made to date, will require consideration, particularly beneath adoptable highways. This could be mitigated by a 2m turnover and placement of a geogrid at the base of excavation, as discussed earlier. However, it is strongly recommended that such a proposal is discussed with the Local Authority Section 38 engineering department to assess/ agree a suitable platform for highway construction.

Area E

The former, now backfilled, reservoirs, ponds and mill race part of this area is arguably one of the most problematic on this site. The predominant settlement mechanism within the former reservoirs, ponds and mill race is possibly creep settlement related. This is owing to the age, thickness, nature of placement and fill type. Adoptable highways, traverse this area, in addition to residential dwellings. In order to remove the risk of continued settlement following construction of the development, it is recommended that either, all structures inclusive of highways and drainage runs are supported upon piles, or that full depth treatment of the infill materials are undertaken. Full depth treatment of fill materials could comprise complete excavation, subsequent classification and likely ex situ stabilisation, for example with lime and/or cement (subject to laboratory suitability analysis) prior to compaction, or if possible/ soils prove suitable, consideration in situ soil mixing techniques.

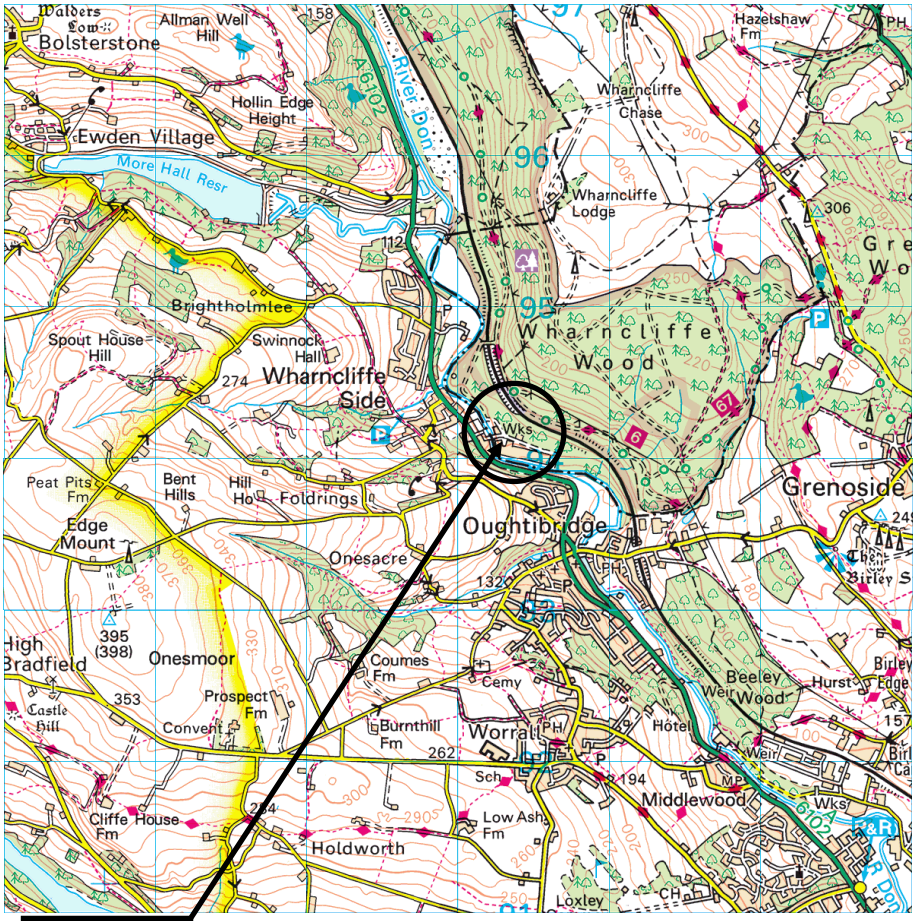
For the embankment part of this area i.e. in the west, site levels will either remain as is, or be subject to significant reduction as the embankment area is reduced to increase development space east of the realigned embankment toe. In some instances, proposed site levels may lead most if not to complete removal of made ground and even in some cases limited excavation into the natural soils. It is considered therefore, that following a re-profiling of the embankment, the area subject to cut will have effectively surcharged any underlying cohesive alluvium, leading to a low risk of excessive settlement beneath the former embankment. Conversely it may be prudent to consider an assessment of potential ground heave as a result of significant stress release following a reduction to proposed site levels.

APPENDIX A

FIGURES AND DRAWINGS

Site Location Plan

Contract Number	**C6485D RevA**
Contract	**Oughtibridge Mill**
Client	**CEG**



THE SITE

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Scale	**1:50,000**		
Drawn by	**SH**	**Approved**	**JF**
Drawing Number	**C6485D RevA/01**		