GEOTECHNICAL &
GEO- ENVIRONMENTAL REPORT
AGGREGATE PRODUCTION AREA,
CELSA, ROVER WAY, CARDIFF

Prepared for:
HARSCO Metals and Minerals

April 2019

Job No: 15264

REPORT TITLE	**:**	**Geotechnical and Geo-environmental Report: Aggregate Production Area, CELSA, Rover Way, Cardiff**
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Executive Summary

HARSCO Metals and Minerals are proposing the development of an asphalt and aggragate production area at the CELSA Manufacturing UK Ltd scrap yard site on the southern side of Rover Way, Cardiff.

The site currently comprises an area of made up ground with a concrete hard standing.

The site is underlain by a mantle of very dense made ground over alluvium. The Mercia Mudstone Group locates beneath the alluvium.

A site investigation comprising six rotary probe boreholes (three shallow, three deep) was performed in April 2019. Groundwater wells were installed in the boreholes and the shallow wells were also used for soil gas monitoring and organic vapour monitoring.

Soil Chemical Testing of the made ground did not detect determinants in excess of the Geneeric Assessment Criteria for a Commercial/Industrial setting.

Several minor exceedances were recorded in groundwater which are not considered significant given the sites setting.

The first round of shallow gas monitoring placed the site in Gas Characteristic Situation 1, requiring no specialist gas protection measures. Photo-Ionisation Detector monitoring did not detect organic vapours. Higher levels of gas have been detected at greater depth, likely associated with organic material within the alluvium. If deep foundations are proposed, a piling risk assessment should be performed to assess the risk of creating a pathway for the gas. Additional gas and groundwater monitoring should be performed

An Envirocheck Report for the site revealed that No Radon Protection is required for new development at the site.

Very dense made ground was encountered beneath the site to a depth of between 7.3m and 7.7m depth. If foundation loads can be kept below 50kN/m2 and 25mm differential settlement can be tolerated between foundations, mass concrete pads, limited to 2.5m x 2.5m could be employed within the made ground, set upon a controlling layer of compacted Type 1 Aggregate. If larger loads or lower tolerances are necessary we would recommend piled foundations extending to the Mercia Mudstone Group.

Any significant site raising would result in settlement of the site due the alluvium.

Soakage testing at the southern boundary of the site recorded high soakage rates within the made ground.

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SECTION 1 Introduction and Proposed Development

HARSCO Metals and Minerals are proposing the development of an Asphalt and Aggregate Production Area within the CELSA Manufacturing UK Limited site, located south of Rover Way, Cardiff.

Terra Firma (Wales) Limited has been commissioned by HARSCO Metals and Minerals to undertake a geo-environmental assessment and geotechnical investigation of the site.

The main objectives of the geo-environmental assessment programme were to:

- Identify the potential environmental liabilities at the site associated with any soil contamination from past site uses.
- Provide a summary of the environmental conditions at the site, together with any necessary remediation works to render the site fit for its intended use.
- Provide recommendations with regard to radon.

The main objectives of the geotechnical site investigation were to:

- Determine the type, strength and bearing characteristics of the shallow superficial deposits.
- Provide recommendations for a suitable and economic foundation solution for the development.
- Provide recommendations with regard to any other geotechnical aspects pertaining to the development.

In order to achieve the above objectives, Terra Firma (Wales) Limited carried out an assessment programme including a review of existing data, followed by a field investigation to determine the prevailing ground conditions and also to collect and analyse soil samples from selected locations around the site.

1.1 Limitations and Exceptions of Investigation

The geo-environmental and geotechnical investigation was conducted and this report has been prepared for the sole internal reliance of Harsco Metals and Minerals and their design and construction team. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Terra Firma (Wales) Limited. If an unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill.

The report represents the findings and opinions of experienced geo-environmental and geo-technical consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may also be required.

The subsurface geological profiles, any contamination and other plots are generalised by necessity and have been based on the information found at the locations of the exploratory holes and depths sampled and tested.

SECTION 2 Review of Existing Data

2.1 Physical Setting, Current Use and Site Conditions

The site locates to the south side of Rover Way, Cardiff, centred on an approximate National Grid Reference of 321275, 176149. The proposed development occupies an approximate plan area of 2.4 hectares. The location of the site is presented in **Figure 2.1**.

Figure 2.1: Site Location (NTS)

The site was visited in March 2019. The site was seen to comprise a large relatively flat open area comprising recovered land made of slag with areas of hardstanding.

The flat area extends beyond the current study site and the area is surrounded by a high metal security fence. An electricity sub-station locates approximately 200m northeast of the site and a gantry passes over the entrance to the site and runs to the northeast of the site.

A concrete hard-standing lies beneath the proposed Asphalt Area whilst the ground beneath the Aggregate Production Area is currently covered with aggregate.

2.2 Site History

The history of the site has been traced using historical Ordnance Survey maps obtained from Landmark Information Group. The maps are presented in **Annex A**. A summary of the sites history is presented in **Table 2.1**;

Table 2.1. Summary of Historical Plans

Dates	On-Site	Off-Site
1880	The site locates on a salt marsh in the estuary. A channel rund to the northeast of the site. The site locates below Mean High Water	Land locates immediately northwest of the site. The land is undeveloped.
1885/1886	As Previously	Tharsis Copper Works locates 1.4 km southwest of the site.
1900/1901	As Previously	Urban development and a Railway Line locate over 1km west of the site.
1919/1920	As Previously	As Previously
1922	As Previously	As Previously
1938/1947	As Previously	Further urban expansion is shown 475m northwest of the site in Splott
1947 (Aerial Photo)	Site can be seen to comprise mud flats	Evidence of Cardiff Airport 550m north of the site.
1947/1954	As Previously	Sewage outfalls locate 250m northeast and 500m east-northeast of the site.
1952/1957	As Previously	Tremorfa Rolling Mill locates 500m southwest of the site. A pumping station locates 470m northeast of the site.
1965	The site comprises part of a large tip extending onto the flats. Mean High Water locates to the east of the reclaimed land	
1975		The tip is shown to have extended southeast. Tracks traverse the tip. A steel rolling mill and other unspecified works locate 300m southwest. Rover Works locate 700m north on Pengam Moor. A school locates 450m northwest.
1982	Study site is undeveloped..	Shows buildings on the current CELSA Works site.
1989	The tips are traversed by railway/tram lines	A substation locates 250m north of the site. Extensive development of industrial buildings at the current CELSA site. A caravan site locates 600m northeast of the site.
1992	As Previously	
2003	As Previously	A superstore locates on Pengam Green 750m northeast of the site.
2009	Study site is labelled as a scrap yard	
2018	Site labelled as a Recycling Site. Conveyors locate within the site	

Note: Distances are approximate

2.3 Geological

2.3.1 Geology

The 1:50,000-scale geological map (British Geological Survey Sheet 263, (1977)) shows the site to be underlain by rocks of the Mercia Mudstone Group. The bedrock is shown to have a superficial cover of estuarine alluvium.

Made Ground is known to cover the site.

2.3.2 Coal Mining

The study site locates outside the South Wales Coal Field.

2.3.3 Radon

The Envirocheck Report states that No Radon protective measures are necessary in the construction of new dwellings or extensions

A copy of the Envirocheck Report is included in **Annex A**.

2.4 Environmental Setting

2.4.1 Hydrogeology and Hydrology

The Envirocheck Report records that the bedrock deposits are beneath the site are classified as a Secondary B Aquifers. Superficial deposits are recorded as Secondary (Undifferentiated).

The nearest surface water feature recorded by the Envirocheck Report locates approximately 300m southeast of the site.

2.4.2 Flooding

The Envirocheck agency and Hydrological Map shows the study site to lie immediately southwest of areas affected by Extreme (i.e. Zone 2) Flooding.

The Surface Water Flood Risk Map shows areas in the vicinity of the site to be affected by low risk (i.e 1,000 yr return) flooding. A site specific assessment is recommended.

A site specific assessment is recommended to ascertain necessary development levels.

2.4.3 Waste

The study site is shown to locate within a landfill operated by British Steel Corporation. The site is shown to have received Inert and Industrial Waste. Numerous other landfills locate within 250m of the study site with wastes including Inert, Household, Industrial and Special Waste.

SECTION 3 Preliminary Qualitative Human Health and Environmental Risk Assessment

3.1 General

The contaminated land regime is set out in Part IIA of the Environmental Protection Act (EPA) 1990 and was introduced on the 1st April 2000 in England and 1st July 2001 in Wales. A similar regime was introduced in Scotland on 14th July 2000. Part IIA was introduced to achieve two aims:

(1) The identification of contaminated land
(2) The remediation of contaminated land that poses an unacceptable risk to human health and/or the environment

Under Part IIA the statutory definition of 'contaminated land' is: any land which appears to the local authority in whose area it is situated, to be in such a condition, by reason 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."

For land to be classified as 'Contaminated Land' there must be a 'pollutant linkage'.

For our definitions of pollution linkage and how we define risk please refer to **Annex B** which includes our classifications of consequence and probability and risk assessment matrix.

3.2 Preliminary Site Conceptual Model

The preceding sections enable a preliminary conceptual model of the site to be drawn up, to illustrate the likely ground conditions beneath the site together with a preliminary assessment of the nature of any underlying aquifer and groundwater movement. The preliminary site conceptual model is used as a model for the design and implementation of the site investigation, whereby areas of potential contamination can be targeted as well as investigating the site as a whole.

3.2.1 Potential Sources of Contamination and Gas

The potential contamination beneath the site, whether in the matrix of soil or any groundwater will be related to site past use and the history of the surrounding area.

Historical map review has revealed that the site comprises recovered land, built up with imported material, most probably from the nearby steel works (i.e. slag). The ground is therefore likely to reflect this origin. The site was more recently described as a scrap yard and recycling site and this is likely to be reflected in the soils chemistry.

There are numerous landfills within 250m of the site and the site itself locates within an area of fill.

We would therefore consider there to be a **high risk** of contamination being present at the site and the risk from soil gas to be **high** on account of the nearby landfills and potential natural peat deposits within the alluvium.

3.2.2 Potential Receptors, Pathways and Risks

There are both human and hydrological receptors to any contamination that may be present on site.

Construction workers will be excavating in soils and will be exposed via dermal contact with soils and dust, ingestion of soil dust and inhalation of soil dust.

Inhalation of asbestos fibres is also a possible risk, if present in the made ground, as is inhalation of vapours.

A commercial end use is proposed. Once developed, future site users will potentially be at risk from the same pathways.

Neighbouring site users and passers-by may potentially be exposed to soil dust, asbestos fibres and vapours during the earthworks phase.

If any contamination is identified this may be leachable, enabling it to mobilise through groundwater within site soils although thick deposits of alluvium are likely to hinder significant migration of dissolved contaminants.

SECTION 4 Field Investigation

4.1 Site Works

A geotechnical and geo-environmental site investigation was carried out between 1st and 5th April 2019.

Terra Firma Wales Ltd were informed that the Aggregate Production Area will continue to operate using mobile plant and consequently the site investigation was targeted on the proposed installation area of the proposed asphalt area.

Six rotary boreholes were performed at the site to assess the density of the made ground and prove the depth of rock-head and to allow the installation of deep and shallow groundwater and gas monitoring wells.

The fieldworks were supervised by Terra Firma (Wales) Limited.

The Rotary Borehole Logs are presented in **Annex C**.

Exploratory hole positions are given on **Figure 4.1.**

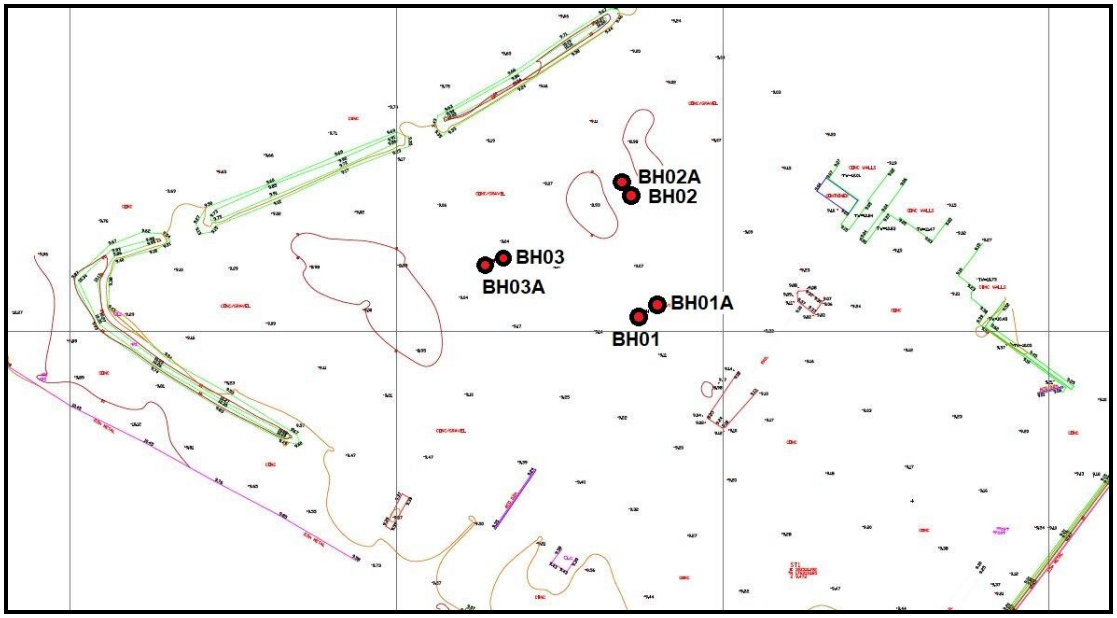


Figure 4.1. Exploratory Hole Locations

4.2 Ground Conditions

Ground conditions were determined from the arisings of the rotary boreholes. In addition to the drill arisings, in-situ testing, and general drilling observations revealed the nature of the material being drilled. A summary of the ground conditions identified in the boreholes is given in **Table 4.1** below.

Table 4.1 Summary of Ground Conditions

Depth (m)	Thickness (m)	Stratum
0.00 - 7.30/7.70 (Not fathomed in BH02A at 7.5m)	7.30/7.70	**CONCRETE over MADE GROUND:** Recovered as predominantly granular, black to grey, with brick and concrete fragments apparent. Material very dense (SPT(C) Values >50)
7.30/7.70 - 15.00/16.40	7.5/8.9	**ALLUVIUM:** Very soft to soft CLAY
15.00/16.40 - >21.00	-	**WEATHERED MARL**

4.3 Groundwater

A perched groundwater body was encountered within the made ground and a sub-artesian groundwater body was encountered beneath the alluvium, rising within boreholes.

During monitoring on the 16th April 2019, the perched groundwater body was encountered at depths of between 4.59m and 4.65m below ground level and the deeper body was encountered between 7.52m and 7.62m below ground level.

4.4 Laboratory Chemical Testing

4.4.1 Exploratory Strategy and Sampling Regime

During rotary drilling small disturbed soil samples of arisings were collected.

The sample locations and depths are listed in **Table 4.2.**

Table 4.2 Sample Locations and Depths

Sample	Depth (m)
BH01	0.50 – 1.50m
BH02	0.50 – 1.50m
BH03	0.50 – 1.50m

4.4.2 Soil Laboratory Analysis

The soil samples taken were despatched to the laboratories of Derwentside Environmental Testing Services Limited.

The following chemical tests were undertaken:

Metals and Metalloids	**In-Organics**	**Others**
Lead	Cyanide	pH (acidity)
Arsenic	Sulphate	Organic Matter
Mercury		Asbestos
Chromium		
Copper		
Nickel		
Zinc		

Organic Chemicals
Phenol
Polycyclic Aromatic Hydrocarbons (PAHs)
Petroleum Hydrocarbons

The laboratory soil chemical test results are presented in **Annex D**.

4.4.3 Groundwater Laboratory Analysis

On 17th April 2019 one round of groundwater monitoring was performed on deep and shallow wells Groundwater samples were tested for the following determinants;

Metals and Metalloids	**In-Organics**	**Others**
Lead	Cyanide	pH (acidity)
Arsenic	Sulphate	Organic Matter
Mercury	$CaCO_3$	COD
Cadmium	BOD	Conductivity
Chromium	Sulphide	
Copper		
Nickel		
Zinc		
Selenium		

Organic Chemicals
Phenols
Polycyclic Aromatic Hydrocarbons (Speciated)
Petroleum Hydrocarbons

The laboratory groundwater chemical test results are presented in **Annex E**.

SECTION 5 Soil and Groundwater Analytical Results

5.1 Soil Assessment Methodology

Comparison of the analytical results have been made with Soil Guideline Values (SGVs) for an Industrial/Commercial setting, sourced from Suitable 4 Use Levels (S4ULs) provided by Land Quality Management Limited, Category 4 Screening Levels (C4SLs) and the Chartered Institute of Environmental Health (CIEH) or CLEA Guidelines. Sulphate results have been compared to British Research Establishment (BRE) guidelines as sulphate levels need only be considered for buried concrete risk assessment only, not human health related.

5.2 Soil Test Results

Table 5.1 Summary of Soil Chemical Test Results Standard Suite and Asbestos

Substance	SGV/ GAC/ S4UL (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		Number of exceedences
			Minimum	Maximum	
Arsenic	640	S4UL	24	29	0
Cadmium	190	S4UL	0.39	0.78	0
Chromium III	8,600	S4UL	96	99	0
Chromium VI	33	S4UL	<0.50	<0.50	0
Copper	68,000	S4UL	37	68	0
Lead	2,330	C4SL	37	64	0
Mercury	1,100	S4UL	0.10	0.15	0
Nickel	980	S4UL	34	40	0
Selenium	12,000	S4UL	2.8	3.3	0
Zinc	730,000	S4UL	140	270	-
Cyanide	480	CLEA	<0.50	0.80	0
Organic matter	-	S4UL	0.60	1.90	-
Sulphate	-	-	3600	5400	-
pH	-	S4UL	9.8	11.6	-
Phenol	440	S4UL	<0.30	<0.30	0
Total PAH	-		<2.0	<2.0	-
Asbestos	-		Not Detected	Not Detected	

Notes
- *See speciated PAH results (Table 5.2)
- 3 samples were tested

5.2 Soil Test Results (Continued)

A summary of the speciated PAH results are given in **Table 5.2** below.

Table 5.2 Summary of Soil Chemical Test Results Speciated PAH

Substance	GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		Exceedences
			Minimum	Maximum	
Naphthalene	190	S4UL	<0.10	<0.10	0
Acenaphthylene	83,000	S4UL	<0.10	<0.10	0
Acenaphthene	84,000	S4UL	<0.10	<0.10	0
Fluorene	63,000	S4UL	<0.10	<0.10	0
Phenanthrene	22,000	S4UL	<0.10	<0.10	0
Anthracene	520,000	S4UL	<0.10	<0.10	0
Fluoranthene	23,000	S4UL	<0.10	<0.10	0
Pyrene	54,000	S4UL	<0.10	<0.10	0
Benzo(a)anthracene	170	S4UL	<0.10	<0.10	0
Chrysene	350	S4UL	<0.10	<0.10	0
Benzo(b)fluoranthene	44	S4UL	<0.10	<0.10	0
Benzo(k)fluoranthene	1,200	S4UL	<0.10	<0.10	0
Benzo(a)pyrene	35	S4UL	<0.10	<0.10	0
Indeno(123cd)pyrene	500	S4UL	<0.10	<0.10	0
Dibenzo(ah)anthracene	3.5	S4UL	<0.10	<0.10	0
Benzo(ghi)perylene	3,900	S4UL	<0.10	<0.10	0

Notes:
- GAC based on 1% soil organic matter content (SOM)
- 3 samples were tested

5.2 Soil Test Results (Continued)

A summary of the speciated Petroleum Hydrocarbon results are given in **Table 5.3** below.

Table 5.3 Summary of Soil Chemical Test Results Speciated Petroleum Hydrocarbons

Substance	GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		Exceedences
			Minimum	Maximum	
ALIPHATIC					
C5 – C6	3,200	S4UL	<1.0	<1.0	0
C6 – C8	7,800	S4UL	<1.0	<1.0	0
C8 – C10	2,000	S4UL	<1.0	<1.0	0
C10 – C12	9,700	S4UL	<1.0	<1.0	0
C12 – C16	59,000	S4UL	<1.0	9.4	0
C16 – C21	1,600,000	S4UL	56	170	0
C21 – C35	1,600,000	S4UL	230	1400	0
C35 – C44	1,600,000	S4UL	<1.0	37	0
AROMATIC					
C5 – C7	26,000	S4UL	<1.0	<1.0	0
C7 – C8	56,000	S4UL	<1.0	<1.0	0
C8 – C10	3,500	S4UL	<1.0	<1.0	0
C10 – C12	16,000	S4UL	<1.0	<1.0	0
C12 – C16	36,000	S4UL	<1.0	1.9	0
C16 – C21	28,000	S4UL	<1.0	16	0
C21 – C35	28,000	S4UL	160	390	0
C35 – C44	28,000	S4UL	<1.0	94	**0**

Notes:
- GAC based on 1% soil organic matter content (SOM)
- 3 samples were tested

5.2 Soil Test Results (Continued)

A summary of the Polychlorinated Biphenyl results are given in **Table 5.4** below.

Table 5.4 Summary of Soil Chemical Test Results Polychlorinated Biphenyls

Substance	GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		Exceedences
			Minimum	Maximum	
PCB 28 + PCB 31	-		<0.01	<0.01	
PCB 52	-		<0.01	<0.01	
PCB 101	-		<0.01	<0.01	
PCB 118	-		<0.01	<0.01	
PCB 153	-		<0.01	<0.01	
PCB 138	-		<0.01	<0.01	
PCB 180	-		<0.01	<0.01	
Total PCB	0.240	CLEA	<0.1	<0.1	**0**

Notes:
- 3 samples were tested

In the absence of Toxic Equivalence Factor (TEF) data for the specific compounds encountered at the site it has been necessary to employ the generic CLEA Soil Guideline Value (SGV) for a commercial setting.

5.3 Groundwater Test Results

A round of deep and shallow groundwater monitoring was performed on 16th April 2019. The result of this round of groundwater testing is presented in **Table 5.5** along with the corresponding Water Framework Directive (WFD) Guidelines or, in their absence, WHO Drinking Water Standards.

Project: 15264 - CELSA A.P.													
Client: Terra Firma (Wales) Ltd	Chemtest Job No.:						19-13651	19-13651	19-13651	19-13651	19-13651	19-13651	
Quotation No.:	Chemtest Sample ID.:				Guideline	Source	814555	814556	814557	814558	814559	814560	
	Sample Location:						BH01	BH01A	BH02	BH02A	BH03	BH03A	
	Sample Type:						WATER	WATER	WATER	WATER	WATER	WATER	
	Date Sampled:						16-Apr-2019	16-Apr-2019	16-Apr-2019	16-Apr-2019	16-Apr-2019	16-Apr-2019	
Determinand	**Accred.**	**SOP**	**Units**	**LOD**									
pH	U	1010		N/A			8.1	9.6	8.1	9.0	8.0	8.8	
Electrical Conductivity	U	1020	µS/cm	1.0			32000	3000	31000	2400	2300	2400	
Biochemical Oxygen Demand	N	1090	mg O2/l	4.0			71	10	72	6.2	32	7.2	Within Standard
Chemical Oxygen Demand	U	1100	mg O2/l	10			290	41	290	25	130	29	Exceeds Standard
Sulphate	U	1220	mg/l	1.0			960	510	960	500	300	490	
Cyanide (Total) Low -Level	N	1300	mg/l	0.0050	0.001	Saltwater WFD	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
Sulphide	U	1325	mg/l	0.050			< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	
Hardness	N	1415	mg/l	1.0			7400	580	7700	620	490	500	
Arsenic (Dissolved)	U	1450	µg/l	1.0	25	Saltwater WFD	29	5.5	27	2.7	13	2.7	
Cadmium (Dissolved)	U	1450	µg/l	0.080	0.25	Inland Surface Water	0.10	< 0.080	0.097	< 0.080	< 0.080	< 0.080	
Chromium (Dissolved)	U	1450	µg/l	1.0			68	10	66	8.3	42	4.7	
Copper (Dissolved)	U	1450	µg/l	1.0	3.76	Saltwater WFD	33	9.1	88	4.8	48	3.4	
Nickel (Dissolved)	U	1450	µg/l	1.0	4	Inland Surface Water	2.7	< 1.0	2.6	< 1.0	1.6	< 1.0	
Lead (Dissolved)	U	1450	µg/l	1.0	1.2	Freshwater WFD	< 1.0	< 1.0	< 1.0	1.0	< 1.0	< 1.0	
Selenium (Dissolved)	U	1450	µg/l	1.0	10	DWD	< 1.0	20	< 1.0	19	47	19	
Zinc (Dissolved)	U	1450	µg/l	1.0	6.8	Saltwater WFD	15	7.5	16	7.5	11	6.0	
Mercury Low Level	U	1460	µg/l	0.010	0.07	Inland Surface Water	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Chromium (Trivalent)	N	1490	µg/l	20	4.7	Freshwater WFD	68	< 20	66	< 20	42	< 20	
Chromium (Hexavalent)	U	1490	µg/l	20	0.6	Saltwater WFD	< 20	< 20	< 20	< 20	< 20	< 20	
Aliphatic TPH >C5-C6	N	1675	µg/l	0.10			< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C6-C8	N	1675	µg/l	0.10	15000	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C8-C10	N	1675	µg/l	0.10	15000	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C10-C12	N	1675	µg/l	0.10	300	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C12-C16	N	1675	µg/l	0.10	300	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C16-C21	N	1675	µg/l	0.10	300	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C21-C35	N	1675	µg/l	0.10			< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aliphatic TPH >C35-C44	N	1675	µg/l	0.10			< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Total Aliphatic Hydrocarbons	N	1675	µg/l	5.0			< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Aromatic TPH >C5-C7	N	1675	µg/l	0.10	10	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C7-C8	N	1675	µg/l	0.10	700	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C8-C10	N	1675	µg/l	0.10	300	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C10-C12	N	1675	µg/l	0.10	90	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C12-C16	N	1675	µg/l	0.10	90	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C16-C21	N	1675	µg/l	0.10	90	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C21-C35	N	1675	µg/l	0.10	90	WHO DWS	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Aromatic TPH >C35-C44	N	1675	µg/l	0.10			< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Total Aromatic Hydrocarbons	N	1675	µg/l	5.0			< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Total Petroleum Hydrocarbons	N	1675	µg/l	10			< 10	< 10	< 10	< 10	< 10	< 10	
Naphthalene	N	1800	µg/l	0.010			< 0.010	1.0	< 0.010	< 0.010	< 0.010	< 0.010	
Acenaphthylene	N	1800	µg/l	0.010			< 0.010	1.9	< 0.010	< 0.010	< 0.010	< 0.010	
Acenaphthene	N	1800	µg/l	0.010			< 0.010	1.9	< 0.010	< 0.010	< 0.010	< 0.010	
Fluorene	N	1800	µg/l	0.010			< 0.010	2.2	< 0.010	< 0.010	< 0.010	< 0.010	
Phenanthrene	N	1800	µg/l	0.010			< 0.010	3.5	< 0.010	< 0.010	< 0.010	< 0.010	
Anthracene	N	1800	µg/l	0.010	0.1	Inland Surface Water	< 0.010	1.5	< 0.010	< 0.010	< 0.010	< 0.010	
Fluoranthene	N	1800	µg/l	0.010	0.0063	Inland Surface Water	< 0.010	0.65	< 0.010	< 0.010	< 0.010	< 0.010	
Pyrene	N	1800	µg/l	0.010			< 0.010	0.66	< 0.010	< 0.010	< 0.010	< 0.010	
Benzo[a]anthracene	N	1800	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Chrysene	N	1800	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Benzo[b]fluoranthene	N	1800	µg/l	0.010	0.017	Inland Surface Water	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Benzo[k]fluoranthene	N	1800	µg/l	0.010	0.017	Inland Surface Water	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Benzo[a]pyrene	N	1800	µg/l	0.010	0.00017	Inland Surface Water	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Indeno(1,2,3-c,d)Pyrene	N	1800	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Dibenz(a,h)Anthracene	N	1800	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Benzo[g,h,i]perylene	N	1800	µg/l	0.010	0.0082	Inland surface Water	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Total Of 6 PAH's	N	1800	µg/l	0.10			< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
PCB 28	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
PCB 52	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
PCB 90+101	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
PCB 118	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
PCB 153	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
PCB 138	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
PCB 180	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Total PCBs (7 congeners)	N	1815	µg/l	0.010			< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Resorcinol	U	1920	mg/l	0.0050			< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
Phenol	U	1920	mg/l	0.0050			< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
Cresols	U	1920	mg/l	0.0050			< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
Xylenols	U	1920	mg/l	0.0050			< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
1-Naphthol	N	1920	mg/l	0.0050			< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
Trimethylphenols	U	1920	mg/l	0.0050			< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	
Total Phenols	U	1920	mg/l	0.030	7.7	Saltwater WFD	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	

Table 5.5. Groundwater

5.4 Soil Gas Monitoring

One round of Soil Gas Monitoring was performed prior to the issue of this report. The results are summarise in **Table 5.6** and are presented in **Annex F**.

Table 5.6. Summary of Gas Monitoring

	CH4 (%)	CO2 (%)	O2 (%)	CO ppm	H2S ppm	FLOW (l/hr)	AP (mb)
SHALLOW WELLS (BH01A – BH03A)							
Minimum	0.2	0.1	17.1	0	0	0.0	1016
Maximum	4.8	1.4	20.2	0	0	0.0	1016
DEEP WELLS (BH01 – BH03)							
Minimum	0.2	0.0	0.2	0	0	0.1	1016
Maximum	47.7	0.1	20.1	0	0	0.0	1016

We understand that there are no buildings proposed as part of the current development. However, based on the results of the first round of gas monitoring the following conclusions are made if buildings were to be constructed.

Based on the results of gas monitoring from the shallow wells a Gas Screening Value of; 0.048 (highest CO_2) x 0.1 (detection limit of flow meter) = 0.0048 l/hr is calculated.

With reference to Table 8.5 of CIRIA C665, this would place the site within Gas Characteristic Situation 1, requiring no special gas protection measures.

Higher levels of gas were detected within the deeper wells, most likely associated with natural organic material in the alluvium. Shallow monitoring has revealed that the deep gas is contained and does not currently affect the shallow ground. However, if piled foundations are proposed, monitoring should be performed during and after the piling to confirm that the piling has not created new pathways to the surface.

The above recommendations are based on a single round of gas monitoring and at least five further rounds of gas monitoring should be performed, under various air pressure conditions, to confirm the above conclusions.

Soil Gas Monitoring results are presented in **Annex F**.

Photo-Ionisation Detector (P.I.D.) monitoring of the wells did not detect any organic vapours.

SECTION 6 Quantitative Risk Assessment

6.1 Contaminants of Concern in Soil

It can be seen from Section 5 that all determinants tested were present at concentrations below the published Generic Assessment Criteria for a Commercial/Industrial Setting. Asbestos was not detected during screening.

Vapour monitoring of the gas wells, using a Photo-Ionisation Detector (P.I.D.), did not detect and organic vapours.

6.2 Contaminants of Concern in Groundwater

A summary of exceedances recorded in shallow groundwater during the first round of monitoring is presented in **Table 6.1**.

Table 6.1. Summary of Shallow Groundwater Exceedances

Determinant	Assessment Criteria (ug/l)	Recorded Concentration (ug/l)	Location
Round 16/04/2019			
Copper	3.76	9.1	BH01A
		4.8	BH02A
Selenium	10	20	BH01A
		19	BH02A
		19	BH03A
Zinc	6.8	7.5	BH01A
		7.5	BH02A
Anthracene	0.1	1.5	BH01A
Fluoranthene	0.0063	0.65	BH01A

A summary of exceedances in deep groundwater is presented in **Table 6.2**.

Table 6.2. Summary of Deep Groundwater Exceedances

Determinant	Assessment Criteria (ug/l)	Recorded Concentration (ug/l)	Location
Round 16/04/2019			
Arsenic	25	29	BH01
		27	BH02
Copper	3.76	33	BH01
		88	BH02
		48	BH03
Selenium	10	47	BH03
Zinc	6.8	15	BH01
		16	BH02
		11	BH03
Chromium III	4.7	68	BH01
		66	BH02
		42	BH03

6.3 Potential Receptors and Pathways

6.3.1 Human Receptors

Construction workers may be in intimate contact with the site soils and are potentially at risk from exposure to determinants within the made ground through dermal contact, ingestion and inhalation pathways.

Neighbouring site users and passers-by are potentially exposed to soil dust during earthworks.

Future site users are potentially at risk from determinants exceeding the Generic Assessment Criteria via dermal contact with soils, inhalation of soils and dust. Development offers an opportunity to address the issues.

It is understood that the existing hard-standing cover is to remain in-situ except at locations where new foundations necessitate its excavation. The site is therefore capped with hardstanding.

6.3 2 Aquatic Environment

Slightly elevated copper, selenium and zinc were encountered in shallow wells during the first round of groundwater monitoring. This is not considered significant given the sites setting. Two exceedances of PAH guidelines were also recorded although the guidelines are very stringent. The High Molecular Weight PAHs have very low solubilities and low mobility characteristics and are unlikely to impact significantly beyond their source.

During the first round of monitoring arsenic copper selenium zinc and chromium III were encountered in the deep wells. Given the sites surroundings the recorded levels are not considered significant and the levels may have originated at an off-site source.

6.4 Mitigation and Remedial Measures

6.4.1 Site Workers

In order to protect construction workers good site management, COSHH, good standards of hygiene and appropriate health & safety on site should be adhered to, with personal protection equipment (PPE) and dust suppression where appropriate. The elected contractor should provide their own risk assessment to mitigate these risks

6.4.2 Neighbouring Site Users

Appropriate dust suppression should be employed to present the migration soil dust during the earthworks phase.

6.4.3 Site End Users

Chemical testing of soils in the proposed excavation areas did not detect determinants in excess of the Generic Assessment Criteria (GAC) for a Commercial/Industrial setting.

We understand that the proposed development will include the retention of hard standing cover in the development area and this should interrupt the pathway between the contaminants and the site end users.

If ground raising is performed, this should be carried out using materials that conform to the Commercial/Industrial GACs.

A Potable Water Supply Pipe Material Assessment should be carried out by the water provider.

If during development works any other unexpected ground conditions or evidence of contamination is found, inspection by a geo-environmental engineer should be made, and any required testing or investigation carried out prior to continuation of works.

6.4.4 Aquatic Environment

Several minor exceedances of metals and PAH were noted during the initial groundwater monitoring although these are not considered to be significant given their magnitude and also the low mobility characteristics of the PAHs.

There is not considered to be significant risks to the aquatic environment from site soils given the sites location.

During the construction period, there is a risk to the environment/adjacent sites from de-watering, digging foundations, moving soil, drainage misconnections, discharges to local surface waters or the ground, runoff from construction materials and/or exposed ground, wheel washings and oil or chemical spills.

The risk is considered to be negligible as any adverse effects will be easily preventable by due diligence to good construction practise and housekeeping in preventing surface runoff and the spillage of materials.

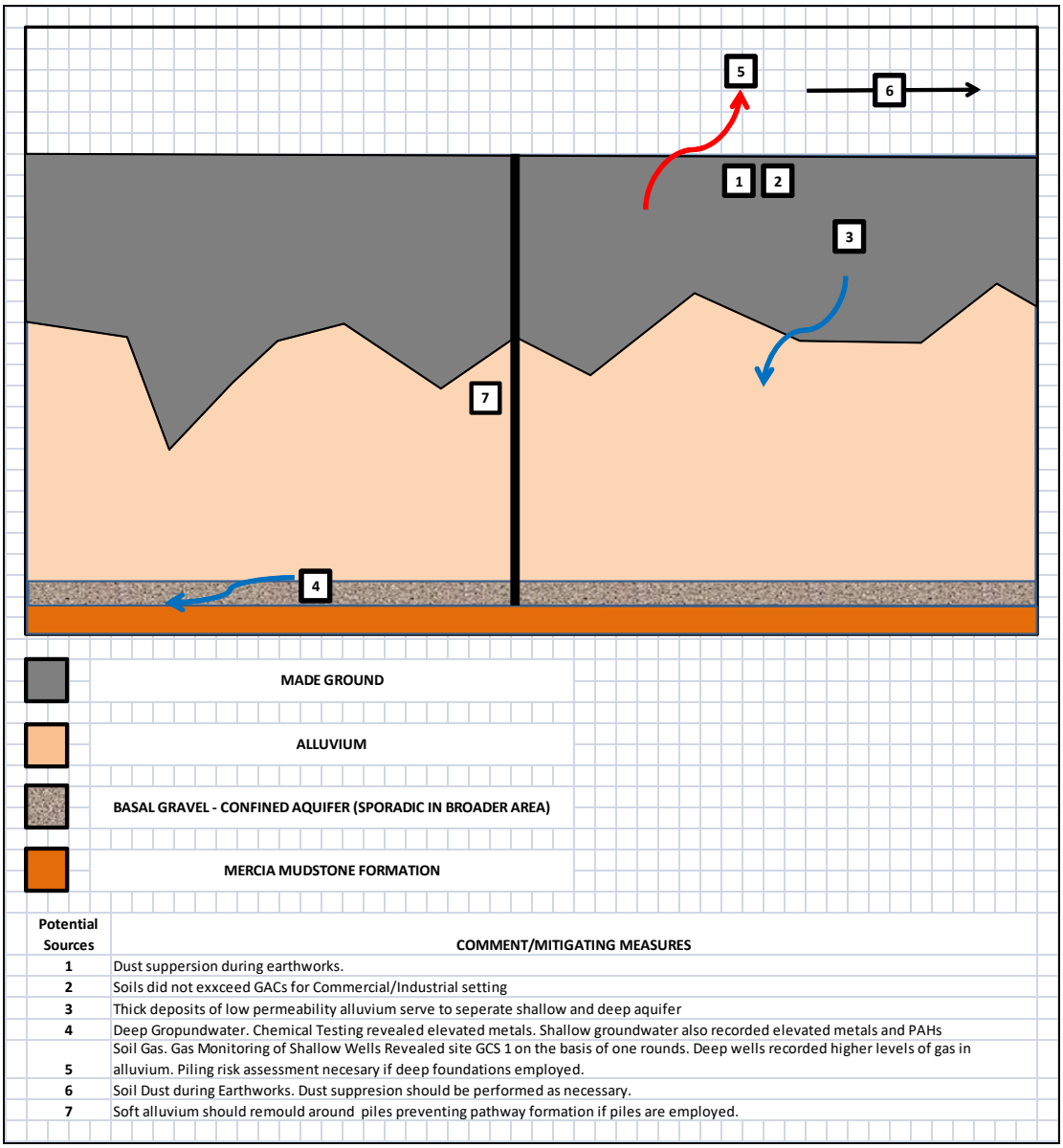
The basic measures that should be taken are as follows:

- Prepare a drainage plan and mark the manholes to prevent pollutants accidently reaching the surface water sewers;
- Carry out any activities that could cause pollution in a designated, bunded area, away from rivers or boreholes. Where possible it should drain to the foul sewer;
- Use settlement ponds or separators to remove silty water;
- Store all oils and chemicals in a fully bunded area to prevent leaks or spills;
- Get advice on whether you need an environmental permit and apply in good time

If piled foundations are to be employed a Piling Risk Assessment, including further rounds of monitoring during and after piling, should be performed.

6.5 Site Conceptual Model

A Site Conceptual Model is presented below;



Potential Sources	COMMENT/MITIGATING MEASURES
1	Dust suppersion during earthworks.
2	Soils did not exxceed GACs for Commercial/Industrial setting
3	Thick deposits of low permeability alluvium serve to seperate shallow and deep aquifer
4	Deep Gropundwater. Chemical Testing revealed elevated metals. Shallow groundwater also recorded elevated metals and PAHs
5	Soil Gas. Gas Monitoring of Shallow Wells Revealed site GCS 1 on the basis of one rounds. Deep wells recorded higher levels of gas in alluvium. Piling risk assessment necesary if deep foundations employed.
6	Soil Dust during Earthworks. Dust suppresion should be performed as necessary.
7	Soft alluvium should remould around piles preventing pathway formation if piles are employed.

Figure 6.1. Site Conceptual Model (note: Not to Scale)

SECTION 7 Engineering Recommendations

It is understood that the proposed Aggregate Area will contain mobile plant and does not, therefore, require permanent foundation. If the proposal changes the design of this area can be reappraised.

It is understood that permanent structures are required in the proposed Asphalt Plant Area. The final foundation solution for this area will depend on the foundation loads and acceptable settlements.

7.1 Preparation of Site

Exposed foundation excavations should be inspected by a Geotechnical Engineer to confirm the absence of soft spots. If identified, soft spots should be excavated out and the excavation backfilled in an engineered fashion using a suitable granular aggregate placed at optimum moisture content in accordance with Series 600 of the Specification for Highway Works.

Contingencies should be made for the protection/diversion of any underground services present beneath the site brought about as a result of the proposed works.

Contingencies should also be made for the protection and any necessary temporary/permanent support of structures adjacent to the site.

Any reduced levels should be brought up to the required levels with well compacted imported granular materials. Department of Transport (DoT) Type 2 sub-base or similar may be used and should be compacted in layers, in accordance with the Specification for Highway Works.

All materials to be removed from site should be taken to an appropriately licensed landfill facility. In accordance with EC Regulation 1272/2008 and Environment Agency Guidance WM3 (v. 1.1/2018) soils and other materials destined for off-site disposal should be classified on the basis of their hazard phrases prior to disposal.

7.2 Foundation and Floor Slab Solution

Ground Investigations have encountered a very dense horizon of made ground over a thick deposit of alluvium. The alluvium in the region is generally soft to very soft silt/clay.

Pad Foundations may be employed if pads are limited to a dimension of 2.5m x 2.5m and foundation loads can be kept below 50 kN/m^2 and differential settlement of 25mm between adjacent pads can be tolerated. Under such circumstances the pads could be placed within the dense made ground fill. The existing fill should be excavated to a depth 1.0m below the base of the pad, and extend below the concrete hardstanding, to ensure the absence of hard spots beneath the pad. This should be backfilled with Type 1 Aggregate to the base of the pad, placed at Optimum Moisture Content in thin compacted layers in accordance Series 600 of the Specification for Highway Works.

If larger foundation loads or lower settlement characteristics are required, foundation loads should be transferred to competent horizons within the Mercia Mudstone Group using piles.

7.2 Foundation and Floor Slab Solution

Hollow round section steel piles driven to a suitable set would be expected to perform satisfactorily with loads of 400kN per pile, at which intensity total settlement should not exceed 10mm and differential settlement between adjacent piles should not exceed half this value. The nominated piling contractor should confirm the final design and performance of the piles. Due to the presence of concrete, dense made ground deposits and potential buried obstructions beneath the site, piles are likely to require pre-bored holes through the made ground.

Vibrations should be monitored during piling and if vibrations cannot be kept within limits consideration should be given to deeper pre-drilling or end-driven piles.

During a site visit it was suggested that the site may be raised using site-won aggregate. If the site is raised this will constitute an additional load and a change in the ground stress regime. If the additional load is spread over a broad area the stress will not decay sufficiently within the made ground horizon and will result in settlement from the alluvium.

Secondary settlement of alluvium can be a protracted process and monitoring can be implemented to prove when the process has ceased. If shallow foundations are installed prior to the cessation of secondary settlement in the alluvium the settlements on the foundation may exceed those stated above. If piles are installed prior to infilling the change in stress regime could result in increased skin friction on the piles.

All foundation formations should be inspected by a suitably qualified Engineer before pouring. The piling contractor may request additional site specific testing/boreholes to confirm the piling design.

7.3 Excavations and Formations

Due to the presence of concrete and the density of the made ground breakers will be necessary for excavation at the site. Buried obstructions may be encountered within the made ground and provision should be made for the use of a breaker to deal with such obstructions.

The sides of any excavations deeper than 1.0m should be supported by planking and strutting or other proprietary means.

The sub-formations/formations will be susceptible to loosening, softening and deterioration by exposure to weather (rain, frost and drying conditions), the action of water (flood water or removal of groundwater) and site traffic.

Formations should never be left unprotected and continuously exposed to rain causing degradation, or left exposed/uncovered overnight, unless permitted by a qualified engineer. All formations should be inspected by a suitably qualified engineer before pouring.

Construction plant and other vehicular traffic should not be operated on unprotected formations. Allowances should be made for special precautions to prevent formation deterioration in addition to the above.

7.4 Foundation Risk Assessment

If piling is proposed at the site a Foundation Risk Assessment should be prepared as a separate document and submitted to Natural Resources Wales prior to the works.

The soft alluvial clays should remould around the round section piles, thus maintaining the current status quo in respect to hydrological protection. This should be confirmed by groundwater monitoring during and after the piling works.

Gas monitoring should also be performed during and after the piling operations to confirm that the piling has not affected the gas regime.

If hollow piles are employed any void space in the centre of the pile should be backfilled with a bentonite cement to achieve a hydrological seal.

7.5 Protection of Buried Concrete

Total Sulphate ranged from 3600 mg/kg to 5400 mg/kg and pH values ranged from 9.8 to 11.6. With reference to Table C2 of BRE Special Digest SD1 the site falls into Aggressive Chemical Environment for Concrete (ACEC) Design Sulphate Class AC-1s.

Sulphate analysis of the made ground at the adjacent CELSA Development Site placed the site within Design Sulphate Class AC-1s.

Chemical Test Results are presented in **Annex E**.

7.6 Sustainable Drainage

In April 2019 HARCO performed three soakage tests on the southern boundary of the study site. The tests were performed in a trial pit measuring 4.5m long, 2.2m wide and 2.0m deep (i.e. within the made ground). The made ground was seen to be predominantly granular.

During the tests up to 2670 litres of water cleared from the pits in less than 9 minutes.

The data from the soakage tests was assessed using the equations of BRE 365. Soil infiltration rates of between 2.98×10^{-3} ms^{-1} and 4.4×10^{-4} ms^{-1} were calculated. We would recommend using the lowest rate for design purposes.

7.7 Soil Waste Classification

3 No. samples of made ground soil were subject to Waste Classification.

On the basis of the soil chemical test results, the soil was classified based on the identified hazard phrases as defined in accordance with waste classification algorithms detailed in Environment Agency publication WM3 (V.1.1., 2018).

Representative compounds were selected for the detected elements for waste classification. Where necessary, appropriate factors were employed to account for differences between elemental and molecular weight.

Total Petroleum Hydrocarbons (TPH) were detected in all samples during TPHCWG analysis, up to a concentration of 2,000 mg/kg. The potential for HP 3(i) was triggered on account of this although Terra Firma Wales Ltd does not expect this hazard to be realised as free product was not noted during the investigation.

Asbestos was not detected during screening.

A summary of the soil classification is presented in **Table 7.1**.

Table 7.1 Summary of Classification

Sample Location	Depth (m)		Waste Classification	EWC Code	Additional Comments
BH01	0.5 – 1.5		Non-Hazardous	17 05 04	
BH02	0.5 – 1.5		Hazardous	17 05 03*	HP8 on account of elevated pH
BH03	0.5 – 1.5		Non-Hazardous	17 05 04	

3 No. samples were also submitted for WAC analysis. An appraisal of the WAC results is presented in **Table 7.2**. The Hazwaste report is presented in **Annex G**.

Table 7.2 Summary of WAC Testing

Location	Depth	Comments
BH01	0.5 – 1.5	**Fails Inert Criteria** on account of elevated TPH, fluoride, sulphate and Total Dissolved Solids
BH02	0.5 – 1.5	**Satisfies Stable Non-Reactive Hazardous Waste Criteria**
BH03	0.5 – 1.5	**Fails Inert Criteria** on account of elevated TPH, fluoride and sulphate

* Sample classified as Hazardous during Total Analysis (i.e. Table 7.1) cannot be classified as Inert on account of WAC Results alone.

Due to the variation in classifications, we would recommend further testing of arisings following excavation to allow waste to be segregated and minimise the amount classified as Hazardous.

The current classification does not include an assessment of invasive plant species. If anomalous materials are encountered during excavation the classification should be revisited.