STDC Prairie Site Phase 1 Enabling Works (Highways)

Eston Road Ground Investigation Report

South Tees Development Corporation (STDC)

19 January 2021

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1. Introduction

Atkins Ltd have been requested by South Tees Development Corporation (STDC) to provide a Ground Investigation Report (GIR) which assesses the ground conditions and engineering and contaminated land risks associated with the development of an access road extension into the Prairie site of the South Tees Development Area (STDA).

1.1. Brief Description of the Project

The South Tees Development Corporation (STDC) was established to promote economic growth and commercial development in the South Tees Area by converting assets into opportunities for business investment and economic growth. The STDC manages the 1,820-hectare area former TATA Steel (TATA) / Sahaviriya Steel Industries UK (SSI) Steelworks site on the River Tees with existing businesses and land suitable for redevelopment. The net land available for redevelopment is 930 hectares and principally comprises former iron and steel works sites in Redcar, Lackenby, Grangetown and South Bank.

South Tees Development Corporation (STDC) have engaged Atkins to provide design services for the stage 1 enabling works which are starting in the south-west corner of the STDA TS3 Prairie site. The first element of these stage 1 enabling works comprises a roundabout and two spur roads being added to the existing Eston Road where it bounds the western side of the site. A four-spur roundabout is proposed to be constructed at a bend in the road where the north-south orientated Eston Road intersects with the east-west orientated Middlesbrough Road East (OSGR E454336, N521084) (the site). The eastern and northern new spur roads are currently proposed to extend some 200m to the north and east respectively with areas to turn around provided at the spur terminals. The works also include upgrading the two existing western and southern road spurs which include the existing Eston Road alignment for 200m south towards the junction with the A66 and to the west into Middlesbrough Road East. These works include opening the culvert carrying the adjacent Holme Beck water course and adding a combined use cycle/footpath. The site is located within the STDA.

There are two proposed culvert crossings associated with Holme Beck passing under the eastern spur adjacent to the roundabout and further north passing under the turning point at the terminal of the northern spur.

The ground investigation data has been collected by Arcadis and AEG as part of the site wide remediation strategy. Atkins also provided scope for some additional ground investigation to be undertaken as part this GIR to support this stage 1 enabling works at Eston Road. This GIR provides an assessment of GI data provided by Arcadis and AEG and a high-level review of existing reports on the Prairie site has been carried out.

The site location plan is presented in Appendix A. The proposed works are presented in the drawing within Appendix D.1.

1.2. Scope and Objectives of the Report

This GIR has been produced in respect of the proposed highway enabling work off Eston Road as part of the stage 1 enabling works, based on the assumption that the proposed work involves the removal of in-situ Made Ground material to 2.5m bgl and replacement with suitable fill material. This report has been undertaken in accordance with Highways England's DMRB section CD622 'Managing Geotechnical Risk'. The report includes;

- Ground model based on GI data from the most recent GI provided by Arcadis and AEG and relevant data from previous ground investigations;
- Characteristic engineering properties of strata encountered including CBR and subgrade stiffness;
- Geotechnical and geo-environmental risk register;
- Conceptual Site Model based on knowledge of the scheme in line with LCRM;
- Summary of geo-environmental testing undertaken;
- Assessment of soil and soil leachate data, risk to human health and controlled water receptors for the proposed highway works;
- CATWaste assessment of soils to provide indication of non-hazardous / hazardous nature of soils;
- Conceptual Model based on results of investigation; and;
- Conclusions and recommendations for future works with respect to the highway works.

1.3. Sources of Information

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- N. England, “Magic Maps,” 2002. [Online]. Available: https://magic.defra.gov.uk/MagicMap.aspx. [Accessed 2020].
- Atkins, Prairie Site Phase 1 Enabling Works (Highways), 2020.
- Arcadis, Grangetown Prairie Area, Former Steelworks, Redcar - Remediation Options Appraisal and Enabling Earthworks and Remediation Strategy Report, June 2020.
- A. E. &. G. Ltd., “Prairie Site Ground Investigation Works Draft Factual Report (Rev.00),” July 2020.
- A. E. &. G. Ltd., “Eston Road Intrusive Works Draft Factual Report (Rev.00),” September 2020.

1.4. Geotechnical Category

This scheme has been classified as a Geotechnical Category 2 project. Defined as conventional types of structures and foundations with no exceptional risks or difficult soil or loading conditions in accordance with Eurocode 7.

1.5. Limitations

The findings contained within this GIR are based on information obtained from a variety of sources which are considered to be reliable. Nevertheless, the authenticity and reliability of the information cannot be guaranteed. Further, it is possible that the work carried out, whilst fully appropriate to meet the requirements of the brief, may not indicate the full extent of ground conditions across the site and the existence of other information sources. Assuming such sources exist, their information could not have been used in the formulation of the findings and options presented in this GIR.

As with risk-based assessments of complex ground conditions, a great deal of emphasis is placed on results of chemical analyses which have been undertaken according to established protocols. It is possible that the Ground Investigation and assessment carried out, whilst appropriate to comply with the agreed scope of works, may not indicate the full extent of conditions beneath the site and the existence of other important information sources. Hence, it should be noted that there might be areas of undetected contamination or environmental media which, if encountered, may require further investigation and specific remedial measures. It should also be noted that Made Ground materials are particularly heterogeneous in nature and although a reasonable sampling regime may have been utilised, it is possible that some areas of contamination were not identified.

This GIR has been based on the scheme proposals current at the time of writing. Should the scheme proposals change as design develops then further review will be required.

2. Existing Information

2.1. Topographic Maps and Aerial Photos

The site comprises a section of Eston Road and the immediately surrounding area as can be seen in the site plan in Appendix A. The site is relatively flat having previously been occupied by various former iron and steel works. Based on the topographical map [1], the elevation of the site is approximately 10m AOD. The elevation of the surrounding area generally slopes downwards to the north-west, to approximately 5m AOD at the River Tees which is 2km north-west of the site. Towards the south-east, the elevation rises gradually to approximately 30m AOD 3km from the site, where it meets the toe of the north-west facing Eston Hills escarpment and the elevation rises sharply to approximately 240m AOD.

2.2. Historical Maps Summary

2.2.1. On site

The earliest available mapping from 1857 indicates the site to be primarily agricultural land with the development of the Eston Road and railway sidings present on site by 1894. These railway sidings and features form part of the Cleveland Steel and Iron works. The majority of the works are located north of the current site boundary, with the exception of a coal conveyor and coke works present within the site boundary shown on maps from 1929 to 1994. The railway sidings have been mostly removed from site by approximately 1983 to 1990. The site is presently Eston road [2] and surrounding derelict land.

All major buildings at the site have been demolished by 2010 and the only dominant remaining structures is the main embankment adjacent to the pump house and the main pipe bridge [3].

Former Prairie site layout plan is presented in Appendix A.2.

2.2.2. Off site

The Middlesbrough to Redcar railway and the Cleveland Steel and Iron Works with associated reservoir and gas works were present adjacent to the north-east of the site from approximately 1894 [3]. Residential developments and allotments are also present adjacent to the east and west of the site with the allotments no longer shown around 1919-1920 [2].

Additional works including a tarmacadam works and engineering works are present approx. 300m to the north-west from approximately 1929.By 1953 the works have expanded on and adjacent to site to include chimneys, cranes, furnaces, tanks, coke ovens, gasholders, blast furnace and other relevant industrial infrastructure [3].

The Cleveland Steel Works and a variety of other industrial infrastructure adjacent to the eastern boundary of Eston Road and the former Eston Branch railway also appears to have been demolished between 1983 and 1990.

The available mapping from 1993-1994 indicates the buildings were once part of the former Cleveland Iron Works and South Teesside Works to the north-west of the site were demolished.

The remaining buildings part of the Cleveland Steel Works were demolished prior to 2000 [4].

2.3. Anticipated Geology

2.3.1. Geological Maps and Memoir

The BGS 1:50,000 sheet map Stockton E033 (1987) [5] indicates the site to be underlain by Made Ground and superficial Glaciolacustrine Deposits of clay and silt with tidal flat deposits present to the north of the site. Underlying the Superficial Deposits, the geological map shows the bedrock at the site comprising Redcar Mudstone Formation sub-cropping to the south and Mercia Mudstone Group sub-cropping to the north, separated by a thin band of Penarth Group. The Redcar Mudstone Formation at the site is relatively thin and its thickness increases towards the south-east, with up to 250m thickness recorded approximately 4km south of the site at Eston Hills escarpment. The Redcar Mudstone Formation is underlain by the Penarth Group, which is approximately 15m thick, which in turn is underlain by the Mercia Mudstone Group of approximately 200m thickness. The succession is dipping approximately 14 degrees north-northwest.

2.3.2. Historical Investigations

A previous study, TS3 Grangetown Prairie – Phase 1 Geo-environmental Desk Study, prepared by CH2M in 2017 [3], was made available to Atkins. The desk study contained a list of historical investigations carried out within the STDC site and summarised the findings based on the historical investigations. The investigation reports were, however, not made available to Atkins.

2.3.3. Preliminary Ground Model

With the BGS sheet map and Lexicon consulted, and in light of the available desk study and historical ground investigations carried out around the site area, the anticipated ground conditions at the site are summarised in Table 2-1 below.

Table 2-1 - Summary of anticipated geology

Deposit	Geological Period	Stratum	Typical Description	Expected Thickness (m)	Expected location
N/A	N/A	Made Ground	Predominately described as comprising sand, gravel, cobbles, and boulders of slag, clinker, brick, concrete and ash as well as other materials including relic foundations.	Variable	Entire site
Superficial	Quaternary Period	Glaciolacustrine Deposits	Historical investigations indicate that the Glaciolacustrine Deposits comprise soft to stiff clays with varying proportions of silt, sand and gravel.	Variable	Entire site
Bedrock	Jurassic Period	Redcar Mudstone Formation	The BGS Lexicon (BGS, 2020) described the Redcar Mudstone Formation as grey, fossiliferous, fissile mudstones and siltstones with subordinate thin beds of shelly limestone in lower part, and fine-grained carbonate-cemented sandstone in upper part; argillaceous limestone concretions occur throughout.	<50	Southern part of the site
	Triassic Period	Penarth Group	The BGS Lexicon (BGS, 2020) described the Penarth Group as grey to black mudstones with subordinate limestones and sandstones; predominately marine in origin.	15	Southern part of the site
	Triassic Period	Mercia Mudstone Group	The BGS Lexicon (BGS, 2020) described the Mercia Mudstone Group as dominantly red, less commonly green-grey, mudstones and subordinate siltstones with thick halite-bearing units in some basinal areas. Thin beds of gypsum/anhydrite widespread; sandstones are also present.	200	Entire site

2.4. Hydrology

2.4.1. Surface Water Features

The River Tees is located approximately 2.00km north-west of the current site. It is classed as a Main River by the Environment Agency [6]. Holme Beck is present and culverted on site with a connector to Knitting Wife Beck approximately 580 m to the east.

The River Tees was assessed by the Environment Agency and classified as 'moderate' quality with ecological classification of 'moderate' and chemical classification of 'fail' [7]

2.4.2. Flooding Records

The Environment Agencies Flood Risk mapping tool [8] indicates that there is a very low to low risk of flooding from rivers or the sea across the site, which means that each year this area has a chance of flooding of less than 0.1% to 1%. Medium to high risk of flooding from surface water, with a chance of flooding greater than 3.3% each year, is recorded at two small areas approximately 15m west of the site and 50m east of the site [9].

There are no flood defences within 250m of the site.

2.5. Hydrogeology

Glaciolacustrine deposits underlying the site are classed as a non-aquifer however the tidal flat deposits present to the north are classified as a Secondary (undifferentiated) Aquifer [10]. Bedrock deposits underlying the site are classed as a Secondary (undifferentiated) Aquifer (Redcar Mudstone Formation) and Secondary B Aquifer (Mercia Mudstone Group and Penarth Group). Secondary B Aquifers are described as, "predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers."

The site is not located within a groundwater source protection zone and there are no abstractions within 1km of the site. The area is likely tidally influenced and therefore potentially saline [6].

2.6. Sensitive Land Uses

The site is approximately 2.00km North-west of the Teesmouth and Cleveland Coast SSSI, the Teesmouth and Cleveland Coast SPA and Ramsar site [10] .

2.7. Landfill Sites

A previous study, TS3 Grangetown Prairie – Phase 1 Geo-environmental Desk Study, by CH2M prepared in 2017 [3], was made available to Atkins . There is one active landfill and one historic landfill within 500 m of the site. Details of each landfill are summarised in Table 2-2 and Table 2-3 below.

Table 2-2 - Summary of active landfills within 500m of the site

Site name	Distance from site	Operator	Site Type
CLE 3/8 Landfill Site	330m north	Sahaviriya Steel Industries UK Limited	L04 – Non Hazardous

Table 2-3 - Summary of historical landfills within 500m of the site

Site name	Distance from site	Dates	Waste type
Bolckow Terrace	500m west	31/03/1978 – 10/06/1985	Inert, industrial and commercial

2.8. Potentially Contaminative Land Use

The site sits within former industrial land which has a long history of heavy industry including iron and steel making and associated auxiliary works [11]. The site sits within the former TATA Steel (TATA) / Sahaviriya Steel Industries UK (SSI) Cleveland Steelworks site.

2.9. Remediation Strategy Review

In June 2020 a remediation strategy was produced by Arcadis for STDC and covers the parcels of land in Redcar, Lackenby, Grangetown and South Bank [12]. The site is known to have an extensive industrial legacy associated with the iron and steel industry and associated contamination. This has been noted to include extensive contamination within Made Ground of variable depths comprising sand, gravel, cobbles, and boulders of slag, clinker, brick, concrete and ash as well as other materials including relic foundations. Slag has been extensively located in Made Ground at site and across the wider site with Made Ground containing up to 75%.

STDC have appointed Seymour Civil Engineering as Contractor to undertake the remediation and highway construction works and the remediation will be overseen by Arcadis. It is proposed that remediation works will be completed first in advance of the highway construction works. The proposed remediation area covers land including and immediately to the east of the site but excludes the current Eston Road. The proposed remediation is anticipated for a capping insitu methodology includes turnover of the Made Ground within the subsurface up to 2.50m bgl. This is to include removal of relic structures, soil contamination removal and treatment, and replacement with treated material to create a suitable development platform. It is proposed by Arcadis that existing concrete, brick and other suitable building materials will be crushed to 6F2 as specified by the Highways Specification to allow for reuse on-site. Arcadis have concluded that the remediation will not target slag or refractory materials as this is considered the responsibility of the developer. NAPL and tar was located on the wider Prairie site and Arcadis have proposed that this material should not be re-used in its current form and either treated or disposed of off-site.

3. Conceptual Site Model

Land contamination is assessed through the identification and assessment of relevant potential pollutant linkage (PPLs). The approach adopted by Atkins is in accordance with Land Contamination: Risk Management (LC:RM) [13] document. The assessment involves the development of a Conceptual Site Model (CSM) which describes the relationship between potential on- and off-site sources of contamination (and contaminants), potential receptors of contamination, and pathways between the two. Where all three (source, pathway and receptor) are present or considered to be present, they are described as a potential pollutant linkage (PPL) which can be subject to the risk assessment process.

Under current health and safety legislation, construction and maintenance contractors are required to carry out their own appropriate risk assessments and mitigation to protect their staff, other human receptors and the environment from potential contamination. Such risks must be adequately mitigated by law, specifically the Construction Design Management (CDM) Regulations, 2015 [14] that require potential risks to human health and the environment from construction activities are appropriately identified and all necessary steps taken to eliminate/manage that risk. Therefore, construction/maintenance workers have been discounted as human receptors from the CSM.

3.1.1. Potential Sources

Based on the review of available information, the following key potentially contaminative sources have been identified within the site boundary and in close proximity to the site.

- On Site:
    - Made Ground including sand, gravel, cobbles, and boulders of clinker, brick, concrete and ash as well as other materials including relic foundations and extensive slag deposits;
    - Made Ground associated with the construction of Eston Road; and,
    - Industrial current and historical legacy from steel works, railways and iron works.

- Off Site:
    - Made Ground including extensive slag deposits; and,
    - Industrial current and historical legacy from steel works, railways and iron works .

Potential contaminants associated with the above sources include:

- inorganics including metals and metalloids, asbestos, cyanide, sulphate, ammonia;
- organics including phenols, Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAHs), benzene, toluene, ethylbenzene, and xylenes (BTEX), volatile and semi volatile organic compounds (VOCs/SVOCs); and,
- Ground gases.

Numerous potentially contaminative off-site sources were identified due to the sites longstanding historic and industrial legacy. The off-site historic and current uses include steel and iron works, electrical substations, tanks, storage facilities, works, railway infrastructure, and landfills etc. However, due to the nature of the proposed works and considering that the off-site potential contaminants are broadly similar to those related to on-site sources it is assessed that these off-site sources do not pose a significant additional risk to future site users and are therefore discounted from further consideration. No confined spaces are anticipated as part of the current proposed development and therefore the risk of off-site gas migration from landfills and Made Ground has been discounted.

3.1.2. Potential Receptors

The following receptors have been identified at the site based on the proposed commercial end use:

- Human Health:
    - On-site - future end users; and,
    - Off-site – commercial workers.

- Controlled Waters:
    - Groundwater – Secondary B Aquifer underlying site and Secondary A Aquifer (Tidal Flats) north of site; and,
    - Surface Water (River Tees, Holme Beck - culverted).
- Property receptors
    - Proposed and present roads;
    - Present services (including drainage); and,
    - Foundations of present structures off-site

3.1.3. Potential Pathways

Considering the identified receptors, a number of pathways are considered plausible based on the information gathered to date. The plausible pathways are:

- Human Health
    - Ingestion of contaminated soils, soil-derived dust and groundwater;
    - Inhalation of soil and soil-derived dust;
    - Inhalation of airborne asbestos fibres
    - Dermal contact with soil, soil-derived dust and groundwater; and,
    - Inhalation of ground gases, and soil- and groundwater-derived vapours.
- Controlled Waters
    - Leaching or dissolution of contaminants in unsaturated soils and subsequent migration;
    - Lateral and vertical migration through Made Ground, superficial deposits and bedrock;
    - Lateral migration between groundwater and surface water;
    - Migration via preferential pathways e.g. services and foundations; and,
    - Surface water run-off (especially in the event of flooding).
- Property and Services:
    - Direct contact of soils and groundwater with foundations / structures / services; and,
    - Ground gas migration and accumulation within confined spaces.

3.2. Qualitative Risk Assessment

Table 3-1 below shows the qualitative risk matrix, based on CIRIA guidance [15], in which the likelihood or probability of each pollutant linkage being realised is ranked against the severity of the consequences. The result is the relative risk classification, the results of which can inform the due diligence process and allow prioritisation of any further assessments or the implementation of risk management measures.

Table 3-1 - Qualitative Risk Matrix

Risk Matrix		Severity of Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability of pollutant linkage	**High Likelihood**	Very High Risk	High Risk	Moderate Risk	Moderate/Low Risk
	Likely	High Risk	Moderate Risk	Moderate/Low Risk	Low Risk
	Low Likelihood	Moderate Risk	Moderate/Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate/Low Risk	Low Risk	Very Low Risk	Very Low Risk

Definitions of the risk classifications presented in the guidance are given in Table 3-2 below.

Table 3-2 - Risk Classifications

Risk Classification	Definition
Very High Risk	There is a high probability that severe harm could arise to a designated receptor from an identified source, or there is evidence that severe harm to a designated receptor is currently happening.
High Risk	Harm is likely to arise to a designated receptor from an identified source.
Moderate Risk	It is possible that harm could arise to a designated receptor from an identified source. However, it is relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild.
Low Risk	It is possible that harm could arise to a designated receptor from an identified source, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low Risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

The individual sources, pathways and receptors identified in previous sections are judged against this risk matrix, and professional judgement has been used to estimate the combination of probability of a pollutant linkage being realised and the consequence of the harm that might result in line with CIRIA C552 [16]. Details of the potential pollutant linkages and associated risks are presented in Table 3-3 below.

Table 3-3 - Conceptual Site Model

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
Potential contaminants in soil/groundwater on-site originating from the following on-site sources: • Made Ground including extensive slag deposits; • Made Ground associated with construction of Eston Road; • Industrial current and historical legacy from steel works, railways and iron works. ***Possible contaminants include:*** • inorganics including metals and metalloids, asbestos, cyanide, sulphate, ammonia; • organics including phenols, Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAHs), benzene, toluene, ethylbenzene, and xylenes (BTEX), volatile and semi volatile organic compounds (VOCs/SVOCs); and, • Ground gases.	Inhalation, ingestion and dermal contact with contaminants in soil, soil derived dust and groundwater	On-site - future end users including commercial site users	*(Medium/Unlikely)* **Low Risk** Given the industrial legacy, Made Ground including slag is expected to be present across the site. Initial enabling works comprises a roundabout and two spur roads being added to the existing Eston Road which will be upgraded where it bounds the western boundary of the site. This is also to include road improvements and cycle pathway south and connecting to the A66. There is anticipated to be extensive cover of hardstanding and this is likely to reduce risks to human receptors on site.
	Inhalation of airborne asbestos fibres		(*Severe/Unlikely*) **Moderate/Low Risk** Due to the industrial legacy of the site, asbestos has been identified within the Made Ground. The risks from asbestos will need to be further assessed as part of the construction works by a suitably qualified and experienced asbestos specialist to assess potential risks to human health receptors. Extensive hardstanding cover is likely to minimise risk to future receptors during use of the road.
	Inhalation of ground gases, and soil- and groundwater-derived vapours		(*Severe/Unlikely*) **Moderate/Low Risk** Given the industrial legacy, extensive Made Ground is present on site to variable depths resulting in a potential source of hazardous ground gas/vapours. Initial enabling works comprises a roundabout and two spur roads being added to the existing Eston Road where it bounds the western side of the wider site. The enabling works will also include road improvements and cycle pathways south and connecting to the A66 and therefore it is currently assumed no confined spaces will be present on site as part of this development.

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
	Inhalation, ingestion and dermal contact with contaminants soil derived dust	Off-site – Commercial workers	*(Medium/Unlikely)* **Low Risk** Given the industrial legacy, Made Ground including slag is expected to be present across the site. Initial enabling works comprises a roundabout and two spur roads being added to the existing Eston Road where it bounds the western boundary of the site. This is also to include road improvements and cycle pathway south and connecting to the A66. There is anticipated to be extensive cover of hardstanding following construction and this is likely to reduce risks to human receptors off site.
	Inhalation of airborne asbestos fibres		(*Severe/Unlikely*) **Moderate/Low Risk** Due to the industrial legacy of the site, asbestos has been identified within the Made Ground however extensive hardstanding cover is likely to minimise risk to receptors off site. The risks from asbestos will need to be further assessed as part of the construction works by a suitably qualified and experienced asbestos specialist to assess potential risks to human health receptors from airborne fibres during construction works.
	Leaching of contaminants to groundwater in superficial deposits and bedrock; Lateral and vertical migration through Made Ground, superficial deposits and bedrock; Migration of contaminants via preferential pathways.	Secondary A Aquifer (off site superficial deposits – Tidal Flats) Secondary B Aquifer Secondary undifferentiated Aquifer	(*Medium/Low Likelihood*) **Moderate/Low Risk** Given the industrial legacy, Made Ground including slag is expected to be present across the site. The site is anticipated to be underlain by clayey strata beneath Made Ground. The anticipated presence of predominantly clayey strata across the site will limit the lateral and vertical migration of any potential contamination present within the soil to the Secondary A Aquifer off-site and the low permeability superficial deposits are unlikely to be a significant source of groundwater. Additionally, the site is not within a groundwater source protection zone.

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
	Lateral migration between groundwater and Holme Beck and River Tees; Surface water run-off; and, Migration of contaminants via preferential pathways.	River Tees	(*Medium/Low Likelihood*) **Moderate**/**Low Risk** The River Tees is present approximately 2.00km north-west of the site and is considered to be at a distance where it is unlikely to be impacted by migration via other pathways and surface water run-off or by migration of groundwater due to the impermeable nature of the superficial and rock strata .
		Holme Beck	(*Medium/Likely*) **Moderate** The Holme Beck is culverted on site and due to the close proximity to the proposed development has the potential to be impacted by the works depending on the current state of the concrete / pipework of the culvert. A connector is present between Holme Beck and Knitting Wife Beck that could act as a potential pathway.
	Direct contact of new and existing structures with contaminants in soils and/or groundwater. Ground gas migration and accumulation within confined spaces	On-site New road spurs and roundabout, road improvements and associated drainage and services	*(Medium/Low Likelihood)* **Low/Moderate Risk** Given the industrial legacy, Made Ground including slag is expected to be present across the site. There is unlikely to be any confined spaces as part of the design and therefore there is unlikely to be any build of ground gases It is expected that services, the road and foundations are likely to come into contact with Made Ground which may be impacted, however appropriate mitigation should be utilised in the design and include appropriate testing for installation of appropriate service channels and pipes.
	Direct contact of existing structures with contaminants in soils and/or groundwater.	Foundations of present structures off-site	*(Medium/Unlikely)* **Low Risk** Given the industrial legacy, Made Ground including slag is expected to be present across the site. However, it is unlikely that contamination from this site will pose unacceptable risk to offsite structures as a result.

4. Field and Laboratory Studies

4.1. Walkover

A walkover survey was not undertaken for the site.

4.2. Ground Investigations

A ground investigation was carried out by Allied Exploration and Geotechnics Ltd (AEG) on behalf of Arcadis and the South Tees Development Corporation between the 1st April 2020 to 1st May 2020 [17]. The investigation comprised the excavation of:

- 10 No. boreholes to 6.80m and 18.40m bgl,
- 122 No. machine excavated trial pits to depths between 0.10m and 5.20m bgl.

This ground investigation covers a wider site area. Therefore, data from this investigation will only be reviewed as part of this GIR if it is within the current site boundary. The data relevant to Eston Road comprised:

- 4 No. boreholes to 9.50m and 20.80m bgl,
- 17 No. machine excavated trial pits to depths between 0.60m and 4.50m bgl.

Atkins were informed that the supplementary ground investigation was carried out by AEG on the edge of Eston Road between the 16th and 19th of June 2020 [18]. The investigation comprised the excavation of:

- 12 No. machine excavated trial pits to depths between 1.30m and 3.50m bgl,
- 3 No. Transport Research Laboratory Dynamic Cone Penetrometers,
- 3 No. Road cores.

4.3. Laboratory Analysis

4.3.1. Geotechnical testing

The geotechnical laboratory testing has been carried out in accordance with BS 1377:1990 [19] to provide information on the geotechnical properties and characteristics of the soils encountered during the ground investigation. Tests included the following:

- Moisture Content and Atterberg Limit Tests;
- Particle Density;
- Wet Sieve Particle Size Distribution Tests;
- Particle Size Distribution by Sedimentation Tests;
- Organic Matter Content
- Sulphate and pH;
- Dry Density / Moisture Content Relationship; and
- California Bearing Ratio.

4.3.2. Geo-environmental Soil testing

Samples were sent to DETs for chemical analysis. Chemical analysis was carried out in accordance with MCERTS and UKAS accredited procedures. A total of 21 samples of Made Ground and 4 samples of natural soils were sent for analysis as part of the Arcadis investigation and an additional five samples of Made Ground as part of the supplementary Atkins investigation. A total of six samples were sent for leachate analysis as part of the Arcadis investigation and an additional seven samples as part of the supplementary Atkins investigation. Soil samples collected as part of the ground investigations carried out at site were analysed for the following suite of determinands.

- Antimony, arsenic, barium, beryllium, boron, cadmium, chromium (total and hexavalent), lead, mercury, copper, nickel, iron, magnesium, manganese, molybdenum, vanadium and zinc;
- Cyanide (total and free) and thiocyanate;

- Total petroleum hydrocarbons (TPH) criteria working group (CWG) with aliphatic/aromatic separation and carbon banding;
- Soil organic matter;
- Sulphate and Sulphur;
- Polycyclic Aromatic Hydrocarbons (PAH) (Speciated 16 USEPA);
- Total phenols;
- pH; and
- Asbestos (presence).

Selected soil samples were also tested for:

- Polychlorinated biphenyls (PCBs);
- Volatile Organic Compounds (VOCs); and,
- Semi-volatile Organic Compounds (SVOCs)

Leachate tests were also scheduled on soil samples and tested for:

- Antimony, arsenic, barium, beryllium, boron, cadmium, chromium (total and hexavalent), lead, mercury, copper, nickel, iron, magnesium, manganese, molybdenum, vanadium and zinc;
- Cyanide (total);
- pH
- Chloride;
- Phenols;
- Ammoniacal nitrogen;
- Sulphate;
- Total petroleum hydrocarbons (TPH) criteria working group (CWG) with aliphatic/aromatic separation and carbon banding; and,
- Polycyclic Aromatic Hydrocarbons (PAH) (Speciated 16 USEPA).

5. Ground Summary

This section provides a summary of the ground conditions encountered during the recent GI work. The Ground Investigation Factual Reports are presented in Appendix B.

5.1. Stratigraphic Summary

The ground conditions encountered during the investigation generally confirm the anticipated geological sequence of Made Ground overlying the Glaciolacustrine Deposits of clay and silt with bedrock of Redcar Mudstone Formation and Mercia Mudstone Group. Penarth Group was not encountered as the full thickness of Redcar Mudstone Formation was not penetrated. Table 5-1 summarises the ground conditions encountered at the site.

Table 5-1 - Summary of ground conditions encountered at the site

Strata	Elevation to top of stratum Range (average) m AOD	Depth to top of stratum Range (average) m	Thickness of stratum Range (average) m	Remarks
Topsoil Dark brown sandy topsoil.	12.09	0.00	0.40	Encountered in PRAIRIE_AUK_BH109 only.
Made Ground (granular) Black / brown / grey, sand and gravel / sandy gravel / gravel / clayey sand / with cobbles and remains associated with the site's extensive industrial legacy of the iron and steel industry. Gravel is fine to coarse subangular to subrounded including slag, coal, ash, macadam, concrete, brick, clinker, sandstone and coke. Cobbles are angular and subangular slag, brick and concrete. Wood and metal.	7.80 – 13.16 (9.91)	0.00	0.40 – 3.50 (not proven) (1.57)	Encountered in all 31 locations. Second layer encountered in ATK_TP_010 at 2.2m bgl and PRAIRIE_AUK_TP177 at 1.2m bgl.
Made Ground (cohesive) Soft to firm brown grey mottled black slightly sandy silty clay with gravel of ash and clinker and cobbles of brick.	8.40 – 12.18 (10.12)	0.40 – 1.80 (0.81)	0.40 – 1.20 (0.83)	Encountered in 7 locations.
Glaciolacustrine Deposits Soft, firm and stiff brown and grey, slightly sandy / slightly sandy slightly gravelly silty clay / clayey silt. Gravel is fine to coarse subangular including sandstone, mudstone, siltstone and coal.	6.30 – 11.66 (8.50)	0.80 – 3.00 (1.50)	4.60 – 12.90 (7.85)	Encountered in all locations where full thickness of Made Ground was penetrated. Thickness decreases from north to south.
Redcar Mudstone Formation Weak to medium strong dark blue grey mudstone distinctly weathered locally destructured, and medium strong light grey siltstone unweathered locally partially weathered.	6.29	5.8	Not proven	Encountered in PRAIRIE_AUK_BH109 only.

Strata	Elevation to top of stratum Range (average) m AOD	Depth to top of stratum Range (average) m	Thickness of stratum Range (average) m	Remarks
Penarth Group	-	-	-	Not encountered within any exploratory holes, but indicated as a thin band on the geological map.
Mercia Mudstone Group Extremely weak to strong red brown mudstone partially weathered, locally destructured, with many interbeds of gypsum.	-6.60 – 1.46 (-1.33)	7.70 – 14.40 (10.23)	Not proven	Encountered in PRAIRIE_AUK_BH107PRAIRIE_AUK_BH108 and PRAIRIE_AUK_BH110

5.2. Ground Profile

The northern part of the site is located on an incline, with the north of the site being at approximately 8m AOD, increasing to approximately 11m AOD at the centre of the site. The southern part of the site is located on higher ground, with elevations ranging from 11m AOD to 13m AOD [1].

5.3. Groundwater Strikes

Table 5-2 below summarises the groundwater strikes encountered during the recent GI works. No groundwater samples were collected as part of the Arcadis and supplementary ground investigation and no groundwater monitoring was carried out at site.

Table 5-2 - Summary of groundwater strikes encountered on site

Exploratory Hole	Depth (m bgl)	Reduced Level (m AOD)	Comments
PRAIRIE_AUK_TP156	0.60	8.35	Encountered within Made Ground
PRAIRIE_AUK_TP159	0.90	8.01	Encountered within Made Ground
PRAIRIE_AUK_TP162	2.80	7.76	Encountered within granular lenses in cohesive Made Ground
PRAIRIE_AUK_TP163	1.10	8.78	Encountered within Made Ground
PRAIRIE_AUK_TP164	2.40	7.60	Encountered at Made Ground/Glaciolacustrine Deposits interface
PRAIRIE_AUK_TP177	1.40	11.58	Encountered within Made Ground
PRAIRIE_AUK_TP178	1.50	11.66	Encountered at Made Ground/Glaciolacustrine Deposits interface
PRAIRIE_AUK_TP181	1.70	8.46	Encountered at Made Ground/Glaciolacustrine Deposits interface
PRAIRIE_AUK_TP189	1.30	11.38	Encountered at Made Ground/Glaciolacustrine Deposits interface
PRAIRIE_AUK_TP192	1.10	8.15	Encountered at Made Ground/Glaciolacustrine Deposits interface
PRAIRIE_AUK_TP200B	3.50	7.03	Encountered within Made Ground
ATK_TP_001	2.10	6.26	Encountered within Made Ground

Exploratory Hole	Depth (m bgl)	Reduced Level (m AOD)	Comments
ATK_TP_004	1.60	7.21	Encountered at Made Ground/Glaciolacustrine Deposits interface
ATK_TP_006	1.20	8.28	Encountered at Made Ground/Glaciolacustrine Deposits interface
ATK_TP_008	0.90	7.84	Encountered within Made Ground
ATK_TP_009	0.60	8.40	Encountered within Made Ground
ATK_TP_010	2.50	7.69	Encountered within Made Ground
ATK_TP_011	0.90	9.81	Encountered within Made Ground at granular Made Ground and reworked clay interface
PRAIRIE_AUK_BH110	10.30	-2.50	Encountered within Glaciolacustrine Deposits

5.4. Potentially contaminative ground

A summary of the encountered Made Ground in all the exploratory holes advanced on and off site have been summarised in Tables 5-3 and 5-4. Made Ground was encountered in all exploratory holes as part of the historic and supplementary GI. The Made Ground encountered was variable in composition, comprising cobbles, gravel, sand and clay, which included the following:

Table 5-3 - Summary of the Made Ground encountered during the supplementary ground investigation which was carried out by AEG in 2020

Granular Made Ground	Generally grey, grey brown and/or brown black gravelly sand/sandy gravel that was occasionally clayey with constituents including ash, slag, concrete and red brick with slag content between 0 to 25%, 20 to 50% and 50 to 75%.
Granular Made Ground and cobbles	Typically, grey, grey brown, grey brown black and/or red brown black sandy gravel with cobbles. Constituents include ash, slag, concrete, brick, metal and clinker with slag content of 0 to 25% and 25% to 50%. Occasional wooden railway sleepers, broken pipe, dolomite, coke and wood encountered.
Granular Made Ground with clayey components	Grey brown and/or red orange brown clayey sandy gravel with cobbles/ sandy gravel with reworked grey brown silty clay bands. Constituents include ash, slag, concrete, brick, metal and clinker with slag content of 0 to 25% to 25% to 50%.
Slag	Grey green blue or grey gravel/gravel with cobbles of 100% slag.

Primary contaminative constituents within the Made Ground are recorded above and include variable content of generally vesicular slag.

Made Ground from the previous ground investigations carried out at the wider site was described and has been taken from the Arcadis remediation report [12]. They describe three types of Made Ground as below:

Table 5-4 - Summary of the Made Ground encountered from the Arcadis Remediation Report.

Slag dominant material	Material which was similarly encountered in the Atkins supplementary GI and contained >50% slag with gravel and cobbles. The slag is described as grey green in colour and vesicular in nature.
Granular Made Ground	This was widely encountered and described as sandy gravel with cobbles, and occasionally clayey in places. Gravel included brick, concrete, slag and additional demolition materials.
Cohesive Made Ground	This was identified generally below granular Made Ground and contained gravel and sand constituents within clay and demolition materials.

PID readings were taken in the Arcadis GI but not carried out for the Atkins supplementary GI. PID readings recorded for the Arcadis GI ranged from <0.10ppm to 6.2ppm.

6. Land Contamination Assessment

6.1. Introduction

The following presents a summary of the soil, and leachate analytical data collected from the ground investigations and provides a preliminary assessment of the results based on the proposed end use for the site.

6.2. Human Health Risk Assessment

6.2.1. Generic Assessment Criteria

The basic approach to risk assessment reported here follows the principles given in LC:RM, [20] i.e. that decisions regarding a site may be informed by:

i. Tier 1 preliminary risk assessment - typically a desk study and site walkover inspection with an assessment of risk considering the likelihood and severity of the potential consequences associated with the potential source-pathway-receptor (S-P-R) linkage(s);
ii. Tier 2 generic quantitative risk assessment (GQRA) - a review of site investigation and monitoring data, the development of an outline and updated CM with an assessment of risk using precautionary Generic Assessment Criteria (GACs) and confirmation of potential pollutant linkage(s) that represent minimal or tolerable risk; and / or
iii. Tier 3 detailed quantitative risk assessment (DQRA) - an assessment of risk based on the use of detailed ground investigation and monitoring data to develop a CM and using Site Specific Assessment Criteria (SSACs) for the relevant pollutant linkage(s) to identify the likelihood of unacceptable risk.

The following sections detail the approaches to the Generic Risk Assessments as detailed in Tier 2 above for assessing the potential impacts in relation to human health.

A GQRA has been carried out to assess the potential long-term risks to human health receptors in relation to the current and future site use and the identified key contaminants of concern. Soils have been screened against GAC based on a commercial end use. The GAC are derived following consideration of inhalation, ingestion and dermal contact with the soil/dust and inhalation of vapours originating from soils.

Construction/maintenance workers involved with site maintenance may have direct contact with soils, however, this cannot be formally assessed through this GQRA because the mode and duration of exposure are different to the scenarios used in determining GAC. It is considered that risks to maintenance and construction ground workers would be managed with the use of appropriate working methods informed by robust risk assessment and implementation of health and safety procedures.

6.2.2. Methodology

In order to identify potential contaminants of concern (CoCs), the soil analytical data have been screened against Atkins derived Soil Screening Values (SSVs) or Category 4 Screening Levels (C4SLs) [21] for a commercial land use derived to be protective of chronic risks to human health.

Atkins has produced SSVs based on minimal toxicological risk for a variety of standard land uses at 1% soil organic matter (SOM) (sand soil type) and 6% SOM (sandy loam soil type) using Contaminated Land Exposure Assessment (CLEA) v1.071 in accordance with Environment Agency guidance [22].

Based on the ratio of genotoxic PAHs to benzo(a)pyrene, the surrogate marker approach for genotoxic PAHs as set out in the C4SL Project Methodology has been adopted.

For some constituents, Atkins have not generated SSVs because C4SL are usually considered appropriate based on a low level of toxicological concern (LLTC).

Twenty-six soil samples from the investigation were analysed for SOM as part of laboratory analysis. The SOM values range from 0.40% to 12%, with an average (geometric mean) SOM of 2.68% across the site. Therefore, it is considered that the GAC for 1% is appropriate for use at the site as a conservative measure.

For compounds arsenic, benzene, benzo(a)pyrene, cadmium, hexavalent chromium and lead the CL:AIRE derived C4SL (based on a low level of toxicological concern) for commercial at 1% SOM has been selected as the assessment criterion. It should be noted that CL:AIRE have not derived C4SLs for a 1% SOM. For all other constituents, where available, the SSV has been selected.

The soils results obtained have been screened against relevant GAC as described above for a commercial end use as this is considered a best fit for proposed developments on site.

The following assumptions have been made during selection of GAC and when screening the data:

- The main risk driving pathways in the top 1 m of soil are the direct pathways that include dermal contact, ingestion and inhalation of non-volatile and volatile contaminants in soil and inhalation of soil-derived dust. The main risk driving pathway below 1 m bgl is inhalation of volatile contaminants;
- No free phase hydrocarbons were identified on the site during the ground investigations. Therefore, the combined assessment criterion (rather than the saturation limits) given by the CLEA model have been used for the relevant PAHs;

Human health GQRA comprises comparison of chemical analysis results for soil samples against appropriate GAC to assess the risk associated with the unsaturated soil source. Concentrations of contaminants which fall below the relevant GACs are considered unlikely to represent an unacceptable risk. Those contaminants that exceed their respective GACs are termed Contaminants of Concern (CoC) and may require further assessment.

6.2.3. Soil Assessment

A total of 26 soil samples were tested as part of the Arcadis and Atkins informed supplementary GI. With the exception of two exceedances for naphthalene and 2 exceedances for arsenic (shown in the table below) recorded above GAC for commercial end use, no further exceedances of the commercial land use GAC were identified in the soil samples tested.

Table 6-1 - Soil Screening Exceedances

Constituent	LOD (mg/kg)	GAC (mg/kg)	Max. value	No. of exceedances	Locations of Exceedances
Arsenic	0.2	635	2100	2	PRAIRIE_AUK_TP162_SO_0170, 1.7m; ATK_TP_011_0090, 0.9m
Naphthalene	0.03	90.1	3500	2	PRAIRIE_AUK_TP179_SO_0140, 1.4m; PRAIRIE_AUK_TP182_SO_0090, 0.9m

TPH concentrations were predominantly recorded below laboratory detection limits. PAH concentrations were below the GAC and recorded above and below the laboratory's limit of detection in samples tested.

PCBs were also less than the limit of detection in all samples tested. An assessment table of the data including the GAC is included in Appendix C.

Exceedances for arsenic and naphthalene were recorded in Made Ground located spread across site and recorded to have a high slag content. It is considered there will unlikely be significant risk to receptors as there is anticipated to be extensive cover of hardstanding and this is likely to reduce risks to human receptors on site. Additionally, Arcadis identified capping in situ as a preferred remediation option and the remediation works will be completed prior to the commencement of the construction of this new highway.

6.2.4. Asbestos

Asbestos screening in the laboratory was undertaken on 13 soil samples, all of which were collected from within the top 1.50 m of material from Made Ground and one sample collected from natural soils. Asbestos was detected above detection limits in four samples sent for quantification. The maximum concentration was recorded at 0.009% at PRAIRIE_AUK_TP150_SO_0150 at 1.50 m bgl as shown in the table overleaf.

Table 6-2 - Asbestos Exceedances

Constituent	LOD (%)	Type	Quantification	Locations of Exceedances
Asbestos	0.001		0.009%	PRAIRIE_AUK_TP150_SO_0150 at 1.50 m bgl.
	0.001		0.002%	PRAIRIE_AUK_TP159_SO_0060 at 0.60m bgl
	0.001		0.001%	PRAIRIE_AUK_TP156A_SO_0030 at 0.3m bgl.
	0.001	Amosite	Small bundles	ATK_TP_001_0060 at 0.60 m bgl.

Asbestos was generally located within granular Made Ground located to the north within the site boundary. It is considered there will unlikely be significant risk to receptors as there is anticipated to be extensive cover of hardstanding and this is likely to reduce risks to human receptors on site. However, further assessment will need to be undertaken by a suitably qualified and experienced asbestos specialist to assess the risk during construction works.

6.3. Controlled Waters Assessment

The controlled waters GQRA has been undertaken to assess the potential risks posed to the identified controlled waters receptors from the migration of contaminants from potential on site sources. To assess the potential risks to the identified receptors, a comparison of leachate concentrations against pertinent Water Quality Standards (WQS) has been undertaken.

6.3.1. Generic Assessment Criteria

The superficial deposits on the site are classified as a non-aquifer, however a Secondary A Aquifer is present to the north of the site. The bedrock underlying the site is classed as a Secondary (undifferentiated) Aquifer (Redcar Mudstone Formation) and Secondary B Aquifer (Mercia Mudstone Group).

On the basis of the above, to assess the potential risks to the identified controlled waters receptors; off-site Secondary A Aquifer (Tidal Flats), on-site Secondary (undifferentiated) and Secondary B Aquifers, Holme Beck, Knitting Wife Beck and the River Tees, the leachate data has been compared against the UK Drinking Water Standards (DWS) for groundwater, and freshwater and transitional Environmental Quality Standards (EQS) presented in “The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015” (WFD Directions 2015) (UK Government, 2015) [23]. Transitional EQS has been used as surface water channels could be brackish/transitional waters and therefore defined as ‘coastal waters’ in terms of The Water Framework Directive.

Minimum detection limits (MDLs) for hexavalent chromium, mercury, nitrite, free cyanide, fluoranthene, and benzo(a)pyrene exceeded the EQS screening criteria applied. This is due to laboratories not being able to achieve sufficiently low method detection levels, however concentrations below the MDLs are considered sufficiently low not to be classed as unacceptable or evidence of significant pollution for the purpose of this assessment.

In line with CL:AIRE guidance on Petroleum Hydrocarbons in Groundwater [24] speciated organics have been assessed in preference of TPH fractions.

Table 6-3 - Soil-derived Leachate Screening Exceedances – EQS

Constituent	Unit	LOD	GAC (mg/l)	Max. Value	No. of Exceedances	Locations of Exceedances
Copper	mg/l	0.0004	0.001	0.0059	9	ATK_TP_001_0060, 0.6m, ATK_TP_004_0140, 1.4m, ATK_TP_004_0280, 2.8m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, ATK_TP_009_0150, 1.5m, PRAIRIE_AUK_TP179_SO_0200, 2m, PRAIRIE_AUK_TP181_SO_0060, 0.6m.
Iron	mg/l	0.0055	1	1.7	1	PRAIRIE_AUK_TP179_SO_0200, 2m.
Lead	mg/l	9E-05	0.0012	0.0042	1	PRAIRIE_AUK_TP181_SO_0060, 0.6m .
Manganese	mg/l	0.0002	0.123	0.89	2	PRAIRIE_AUK_TP163_SO_0120, 1.2m, PRAIRIE_AUK_TP179_SO_0140, 1.4m.
Zinc	mg/l	0.0013	0.0139	0.016	1	1702412, ATK_TP_009_0050, 0.5m.
Ammoniacal Nitrogen as N	mg/l	0.015	0.2	1.6	2	PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP179_SO_0200, 2m.
PAHs						
Naphthalene	mg/l	5E-05	0.002	11	5	PRAIRIE_AUK_TP163_SO_0120, 1.2m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP179_SO_0140, 1.4m, PRAIRIE_AUK_TP179_SO_0200, 2m, PRAIRIE_AUK_TP182_SO_0090, 0.9m.
Anthracene	mg/l	1E-05	0.0001	0.057	10	ATK_TP_001_0060, 0.6m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, PRAIRIE_AUK_TP163_SO_0120, 1.2m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP179_SO_0140, 1.4m, PRAIRIE_AUK_TP179_SO_0200, 2m, PRAIRIE_AUK_TP181_SO_0060, 0.6m, PRAIRIE_AUK_TP182_SO_0090, 0.90m.

Constituent	Unit	LOD	GAC (mg/l)	Max. Value	No. of Exceedances	Locations of Exceedances
Fluoranthene	mg/l	1E-05	0.0000063	0.066	13	ATK_TP_001_0060, 0.6m, ATK_TP_004_0140, 1.4m, ATK_TP_004_0280, 2.8m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, ATK_TP_009_0150, 1.5m, PRAIRIE_AUK_TP163_SO_0120, 1.2m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP179_SO_0140, 1.4m, PRAIRIE_AUK_TP179_SO_0200, 2m, , PRAIRIE_AUK_TP181_SO_0060, 0.6m, PRAIRIE_AUK_TP182_SO_0090, 0.9m.
Benzo(a)pyrene	mg/l	1E-05	0.00000017	0.019	10	ATK_TP_001_0060, 0.6m, ATK_TP_004_0140, 1.4m, , ATK_TP_004_0280, 2.8m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, ATK_TP_009_0150, 1.5m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP181_SO_0060, 0.6m, PRAIRIE_AUK_TP182_SO_0090, 0.9m.

Table 6-4 - Soil-derived Leachate Screening Exceedances – Transitional EQS

Constituent	Unit	LOD	GAC (mg/l)	Max. Value	No. of Exceedances	Locations of Exceedances
Copper	mg/l	0.0004	0.00376	0.0059	4	ATK_TP_004_0140, 1.4m, ATK_TP_007_0090, 0.9m, ATK_TP_009_0050, 0.5m, PRAIRIE_AUK_TP181_SO_0060, 0.6m
Iron	mg/l	0.0055	1	1.7	1	PRAIRIE_AUK_TP179_SO_0200, 2m
Lead	mg/l	9E-05	0.0013	0.0042	1	PRAIRIE_AUK_TP181_SO_0060, 0.6m
Zinc	mg/l	0.0013	0.0079	0.016	1	ATK_TP_009_0050, 0.5m
pH*	pH		7 - 9.0	6.8	3	ATK_TP_004_0140, 1.4m, ATK_TP_004_0280, 2.8m, ATK_TP_009_0050, 0.5m
PAHs						
Naphthalene	mg/l	5E-05	0.002	11	5	PRAIRIE_AUK_TP163_SO_0120, 1.2m PRAIRIE_AUK_TP175_SO_0080, 0.8m PRAIRIE_AUK_TP179_SO_0140, 1.4m PRAIRIE_AUK_TP179_SO_0200, 2m PRAIRIE_AUK_TP182_SO_0090, 0.9m
Anthracene	mg/l	1E-05	0.0001	0.057	10	ATK_TP_001_0060, 0.6m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, PRAIRIE_AUK_TP163_SO_0120, 1.2m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP179_SO_0140, 1.4m, PRAIRIE_AUK_TP179_SO_0200, 2m, PRAIRIE_AUK_TP181_SO_0060, 0.6m, PRAIRIE_AUK_TP182_SO_0090, 0.9m
Fluoranthene	mg/l	1E-05	0.0000063	0.066	13	ATK_TP_001_0060, 0.6m, ATK_TP_004_0140, 1.4m, ATK_TP_004_0280, 2.8m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, ATK_TP_009_0150, 1.5m, PRAIRIE_AUK_TP163_SO_0120, 1.2m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, , PRAIRIE_AUK_TP179_SO_0140, 1.4m, , PRAIRIE_AUK_TP179_SO_0200, 2m, PRAIRIE_AUK_TP181_SO_0060, 0.6m, PRAIRIE_AUK_TP182_SO_0090, 0.9m

Constituent	Unit	LOD	GAC (mg/l)	Max. Value	No. of Exceedances	Locations of Exceedances
Benzo(a)pyrene	mg/l	1E-05	0.00000017	0.019	10	ATK_TP_001_0060, 0.6m, ATK_TP_004_0140, 1.4m, ATK_TP_004_0280, 2.8m, ATK_TP_007_0090, 0.9m, ATK_TP_007_0280, 2.8m, ATK_TP_009_0050, 0.5m, ATK_TP_009_0150, 1.5m, PRAIRIE_AUK_TP175_SO_0080, 0.8m, PRAIRIE_AUK_TP181_SO_0060, 0.6m, PRAIRIE_AUK_TP182_SO_0090, 0.9m

*pH values are not maximum but rather above or below a range.

Table 6-5 - Soil-derived Leachate Screening Exceedances – DWS

Constituent	LOD (mg/l)	GAC (mg/l)	Max. Value	No. of Exceedances	Locations of Exceedances
Iron	0.0055	0.2	1.7	3	PRAIRIE_AUK_TP163_SO_0120, 1.2m; PRAIRIE_AUK_TP179_SO_0200, 2m; PRAIRIE_AUK_TP182_SO_0090, 0.9m
Manganese	0.0002	0.05	0.89	4	PRAIRIE_AUK_TP163_SO_0120, 1.2m; PRAIRIE_AUK_TP175_SO_0080, 0.8m;PRAIRIE_AUK_TP179_SO_0140, 1.4m; PRAIRIE_AUK_TP182_SO_0090, 0.9m
Cyanide, Total	0.04	0.05	2.2	4	ATK_TP_009_0050, 0.5m; PRAIRIE_AUK_TP163_SO_0120, 1.2m; PRAIRIE_AUK_TP179_SO_0140, 1.4m; PRAIRIE_AUK_TP182_SO_0090, 0.9m
Ammoniacal Nitrogen as N	0.015	0.39	1.6	2	PRAIRIE_AUK_TP175_SO_0080, 0.8m; 1665615, PRAIRIE_AUK_TP179_SO_0200, 2m
Benzo(a)pyrene	1E-05	0.00001	0.019	10	ATK_TP_001_0060, 0.6m; ATK_TP_004_0140, 1.4m; ATK_TP_004_0280, 2.8m; ATK_TP_007_0090, 0.9m; ATK_TP_007_0280, 2.8m; ATK_TP_009_0050, 0.5m; ATK_TP_009_0150, 1.5m;, PRAIRIE_AUK_TP175_SO_0080, 0.8m; PRAIRIE_AUK_TP181_SO_0060, 0.6m; PRAIRIE_AUK_TP182_SO_0090, 0.9m

6.3.2. Soil Leachate Results

A total of 13 samples were tested for their leachability of contaminants. Several exceedances of metals, inorganics and organics have been recorded against WQS as outlined in Table 6-3, Table 6-4 and Table 6-5above. A more detailed assessment table of the data including WQS is presented in Appendix C.

The following CoC have been identified in relation to the controlled waters receptors:

- soil-derived leachate (EQS) (Holme Beck): copper, iron, lead, manganese, zinc, ammoniacal nitrogen, , naphthalene, anthracene, fluoranthene and benzo(a)pyrene.
- soil-derived leachate (EQS transitional) (River Tees): copper, iron, lead, zinc, pH, naphthalene, anthracene, fluoranthene and benzo(a)pyrene.
- soil-derived leachate (DWS): iron, manganese, total cyanide, ammoniacal nitrogen, and benzo(a)pyrene.

Groundwater at the site appears to be present within the Made Ground as perched water and strikes were seen during the GI between the interface of the Made Ground and the low permeability superficial deposits below. Based on the low permeability of the rock deposits at the site, significant vertical flow of groundwater to aquifers or flow of groundwater towards the River Tees is considered to be unlikely.

Exceedances are generally the same order of magnitude above the EQS for metals and inorganics and were generally recorded in Made Ground. The EQS for lead, zinc and copper assesses the bioavailable concentration of the respective metal, which is controlled by water quality parameters of the receiving surface water body (controlled waters receptor). However, the results recorded represent the total concentration of these metals. No data has been collected for the surface water receptor and as such the EQS for these metals are considered conservative. Considering the concentrations recorded and isolated exceedances recorded generally, there is considered to be a low risk to the Holme Beck.

Exceedances of PAHs are recorded up to a maximum of five orders of magnitude above the EQS. Whilst laboratory leachate testing is generally more aggressive than in-situ conditions and may not be representative of actual leaching conditions, potentially overestimating the concentrations, it is expected there is an on-site source of contamination. The sites industrial legacy, constituents including a high slag content within the Made Ground are widespread across the site. Considering the proximity of the Holme Beck to the proposed development and the elevated concentrations of PAHs recorded, there is likely to be a potentially unacceptable risk to the Holme Beck prior to any site wide remediation taking place depending on the current state of the culvert.

Exceedances of metals, inorganics and benzo (a) pyrene of the DWS are between one to three orders of magnitude above the DWS. Owing to the sites industrial legacy, constituents including a high slag content within the widespread Made Ground across the site, likely represent an on-site source.

However, it should be considered that the exceedances of contaminants identified in soil leachate are unlikely to present a potentially unacceptable risk to controlled waters due to the following lines of evidence:

- Laboratory leachate testing is generally more aggressive than in-situ conditions and may not be representative of actual leaching conditions, potentially overestimating the concentrations;
- No licensed groundwater abstractions are present within 1km of the site and the site is outside of a Groundwater SPZ;
- Due to the industrial legacy of the site and resulting contamination, groundwater resources are unlikely to be utilised in the wider area; and,
- Considering the concentrations of metals, inorganics and benzo (a) pyrene noted within leachate samples, the likelihood of attenuation along with the limited potential for migration due to the low permeability deposits underlying the Made Ground, the risk to groundwater from these CoCs is considered to be low.

Remediation is proposed to be undertaken for the site to include turnover of Made Ground up to 2.50 m in depth prior to road construction. This is to include removal of relic structures, environmental contamination removal and treatment, and replacement with treated material to create a suitable development platform with capping in-situ proposed. However, at the time of writing this report, this remediation had not been completed but it is expected that remediation will be complete on site by Seymour Civil Engineering and overseen by Arcadis prior to the commencement of the highway construction works. Once this work is complete, this should mitigate additional risks to Holme Beck by removing and capping the source.

7. Updated Conceptual Model

Following the human health, and controlled waters risk assessments, the CM has been updated and is presented in Table 7-1 below.

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Table 7-1 - Updated Conceptual Model

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
Potential contaminants in soil/groundwater on-site originating from the following on-site sources: • Soil (arsenic, naphthalene and asbestos); • Soil leachate (copper, iron, lead, manganese, zinc, ammoniacal nitrogen, total cyanide, pH, naphthalene, anthracene, fluoranthene and benzo(a)pyrene).	Inhalation, ingestion and dermal contact with contaminants in soil and soil derived dust	On-site - Future end users including commercial site users	*(Medium/Unlikely)* **Low Risk** Extensive Made Ground with slag was present across the site. Two exceedances for naphthalene and arsenic were respectively recorded above GAC for commercial end use. No further exceedances of the commercial end use GAC were identified in the soil samples tested. Initial enabling works comprises a roundabout and two spur roads being added to the existing Eston Road where it bounds the western side of the wider site. This also includes road improvements and a cycle pathway south and connecting to the A66. It is considered there will unlikely be significant risk to receptors as there is anticipated to be extensive cover of hardstanding and this is likely to reduce risks to human receptors on site. Additionally, Arcadis identified capping insitu as a preferred remediation option which will also mitigate risks to human health receptors and will be completed prior to the commencement of development on site.
	Inhalation of airborne asbestos fibres		(*Severe/Unlikely*) **Moderate/Low Risk** Asbestos has been identified within the Made Ground and above detection limit. Extensive hardstanding cover is likely to minimise risk to future receptors. However, the risks from asbestos will need to be further assessed as part of the construction works by a suitably qualified and experienced asbestos specialist to assess potential risks to human health receptors.

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
	Migration of gases/vapour into open spaces Inhalation of vapours or ground gas (asphyxiation).		(*Severe/Unlikely*) **Moderate/Low Risk** Extensive Made Ground is present on site to variable depths and there is the possibility for hazardous gas generation. Initial enabling works comprises a roundabout and two spur roads being added to the existing Eston Road where it bounds the western side of the site. This also includes road improvements and cycle pathways south and connecting to the A66. Therefore, it is currently assumed no confined spaces will be present on site as part of this development.
	Inhalation, ingestion and dermal contact with contaminants in soil and soil derived dust	Off-site – Commercial workers	*(Medium/Unlikely)* **Low Risk** Extensive Made Ground with slag was present across the site. Two exceedances for naphthalene and arsenic were respectively recorded above GAC Initial enabling works comprises a roundabout and two spur roads being added to the existing Eston Road where it bounds the western boundary of the site. This also includes road improvements and cycle pathway south and connecting to the A66. Surrounding land use comprises warehouse and storage commercial properties. There is extensive hardstanding cover and this is likely to reduce risks to human receptors off site. The potential risk of dust generation during construction will need to be managed by the contractor.
	Inhalation of airborne asbestos fibres		(*Severe/Low Likelihood*) **Moderate Risk** Asbestos has been identified within the Made Ground however extensive hardstanding cover is likely to minimise risk to receptors off site. The risks from asbestos will need to be further assessed as part of the construction works by a suitably qualified and experienced asbestos specialist to assess potential risks to human health receptors.

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
	Leaching of contaminants to groundwater in superficial deposits and bedrock. Lateral and vertical migration through Made Ground, superficial deposits and bedrock; Migration of contaminants via preferential pathways.	Secondary A Aquifer (off-site superficial deposits – Tidal Flats) Secondary B Aquifer Secondary undifferentiated Aquifer	(*Medium/Unlikely*) **Low Risk** Extensive Made Ground with slag was present across the site. The site is underlain by impermeable beneath Made Ground. groundwater strikes were identified in the Made Ground or at the interface between the superficial deposits, suggesting that there is perched water in the Made Ground which is sitting on top of the impermeable clay. The presence of predominantly clayey strata beneath the Made Ground across the site will limit the lateral and vertical migration of any potential contamination present within the soil to the Aquifers.
	Lateral migration between groundwater and Holme Beck and River Tees; Surface water run-off; and, Migration of contaminants via preferential pathways.	River Tees	(*Medium/Unlikely*) **Low Risk** The River Tees is present approximately 2.00 km north-west of the site and due to the impermeable nature of the geology beneath the site is considered to be at a distance where it is unlikely to be impacted by potential contaminants within groundwater or via migration via other pathways and surface water run-off.
		Holme Beck	*(Medium/Likely)* **Moderate Risk** A connector is present between Holme Beck and Knitting Wife Beck that could act as a potential pathway. Identified concentrations within soil leachate samples and proximity to site indicate a Moderate risk, depending on the current condition of the culvert.

Sources	Pathway	Receptor	(Consequence/Probability) Classification of Risk
	Direct contact of new and existing structures with contaminants in soils and/or groundwater. Ground gas migration and accumulation within confined spaces (not expected within the current development)	New road spurs and roundabout, road improvements and associated drainage and services	*(Medium/Low likelihood)* **Low/Moderate Risk** Extensive Made Ground with slag was present across the site. There is unlikely to be any confined spaces as part of the design and therefore unlikely to be any build of ground gases. It is expected that services, the road and foundations are likely to come into contact with Made Ground which may be impacted, however appropriate mitigation should be utilised in the design and include appropriate testing for installation of appropriate service pipes. BRE testing carried out at site has categorised the site as ACEC class DS-1 / AC-1.
	Direct contact of existing structures with contaminants in soils and/or groundwater.	Foundations of present structures off-site	*(Medium/Unlikely)* **Low Risk** Given the industrial legacy, Made Ground including slag is expected to be present across the wider site. Arcadis identified capping in situ as a preferred remediation option which will also mitigate risks to off-site receptors as part of the source will be capped and/or remove. It is unlikely that contamination from this site will pose unacceptable risk to offsite structures as a result.

8. Potential Re-use and Disposal of Materials

8.1. Guidance and permitting

The on-site re-use of soils may be undertaken either under the Environmental Permitting Regulations 2007 (EPR) [25], or under the approach discussed in the CL:AIRE Definition of Waste: Development Industry Code of Practice (CoP) Version 2 [26] which was published in March 2011 and is accepted as an alternative regime to the EPR.

Under the EPR, material that is contaminated but otherwise suitable for re-use is classified as waste, and its re-use should be in accordance with the EPR. Since March 2010, Environmental Permit Exemptions (EPE) have been very restricted in their applicability to construction projects with only very small quantities falling within the EPR regime.

Under the CL:AIRE voluntary CoP [26], materials excavated on-site and not deemed contaminated are suitable for re-use within the site. Consequently, material that may have been classified as hazardous waste under the EPR may be re-used. The CoP regime requires that a 'Qualified Person', as defined under the CoP, reviews the proposed Materials Management Plan (if required to be produced), including review of Risk Assessments and Remediation Strategy / Design Statement together with documentation relating to Planning and Regulatory issues.

8.2. Re-use of site won material

A cautious approach should be taken for areas which are to be adopted by Redcar and Cleveland Borough Council. The area is to be compliant with Tees Valley Design Guide and the key requirements include the avoidance of the use of slag material in road construction and the provision for the use of an inert 'capping' layer over any contaminated material. On the basis that the site arising material largely contains slag and some potential for asbestos, it is not anticipated that Made Ground will be re-used as part of the road construction. However, there may be scope to re-use Made Ground in landscaping, subject to the nature of the material and potential for suitable capping / topsoil and agreement from Landscaping specialists.

Localised exceedances against the commercial GAC were identified at two locations for naphthalene and two locations for arsenic. Exceedances of soil-derived leachate concentrations for a number of contaminants have been identified on-site. In addition, asbestos has been found in three samples above detection limit. Therefore, further assessment will be needed to assess the suitability of re-use for the Made Ground material at the site (if required) in addition to the production of a Material Management Plan for the development. Material management will also need to be considered as part of any remediation works.

8.3. Classification of materials for off-site disposal

8.3.1. CAT-WASTE Assessment

As part of the future developments on-site, material may be removed as part of the re-development of the site if it is not geotechnically suitable to be built on.

Material that is surplus to requirements and that has no clear strategy for re-use on-site (or off-site) is classified as waste and should be disposed of in accordance with the Duty of Care as specified in the Waste Regulations [27]. If the proposals do not require all excavated material to be retained on-site and there is no capacity for it to be re-used elsewhere, then it is a waste.

To classify materials that may potentially be excavated across the site during construction works and require disposal to landfill, a number of steps are required as part of the WM3 Regulations [28] and the Waste Regulations. The initial steps are to identify:

i. if the materials are waste and whether classification is required;
ii. whether the waste is required to be classified at all;
iii. the relevant List of Waste (LoW) codes;
iv. the chemical composition of the material; and,
v. if the substances in the waste are 'hazardous substances' or 'Persistent Organic Pollutants'.

A preliminary waste assessment has been undertaken using the online Atkins waste classification tool CAT-WASTE Soil [29]. CAT-WASTE Soil has been designed to cover the European Waste Catalogue code number 17 05 03 “soil and stones containing dangerous substances”. The assessment of chemical data to determine the potential non-hazardous / hazardous status has been developed with careful adherence to the relevant authoritative guidance.

CAT-WASTE Soil provides preliminary waste characterisation only and is based on the limited number of samples scheduled for analysis. Actual material to be removed off-site for disposal must be appropriately tested (WAC analysis), classified and disposed of in agreement with the chosen landfill operator.

Analytical results from 26 soil samples tested as part of the Atkins investigation were uploaded into CAT-WASTE Soil and the output of the tool is provided in Appendix F. Four samples were recorded as hazardous waste at locations PRAIRIE_AUK_TP162_SO_0170, PRAIRIE_AUK_TP157_SO_0080, PRAIRIE_AUK_TP182_SO_0090 and ATK_TP_011_0090, all remaining samples were classified as non-hazardous.

Should any material from site be considered for off-site disposal, liaison with landfill operators should be undertaken prior to disposal. Copies of the laboratory analysis undertaken on soil samples from site should be presented to the waste disposal / landfill operator(s) so that they can confirm their requirements.

Material that needs to be discarded (e.g. because of contamination / engineering properties, or surplus to the development requirements), including water which should be collected and disposed of as part of wheel washing operations, is waste and should be disposed of in accordance with the current relevant regulations. These include, but are not limited to, Duty of Care, the Landfill Regulations, the Hazardous Waste Regulations and Publication WM3.

8.1. Verification Testing of Imported Material

Prior to the highway construction, remediation using capping insitu is proposed for the wider site area to include turnover of Made Ground up to 2.50 m in depth. This is to include removal of relic structures, environmental contamination removal and treatment, and replacement with treated material to create a suitable development platform. This material will follow requirements as per the remediation strategy from Arcadis and subsequent verification.

If required, the appointed contractor will be responsible for ensuring that any imported material required, dependent on the level of the development platform, for the project is suitable for use on the site. This will include ensuring that material does not contain contaminants which may impact on identified receptors. Material to be imported onto site should be agreed with a suitably qualified engineer and will likely require evidence from chemical testing of material (for example if imported material is not virgin quarried material) and might need to be managed using a Materials Management Plan (MMP).

9. Ground Conditions and Material Properties

This section provides geotechnical summaries and interpretations of each soil and rock type encountered at the site during the recent GI. The summaries also include indicative parameters and the basis for the chosen values. However, further consideration is recommended for design with due consideration of the potential variability of the soils and the sensitivity of the design to such variations.

Geological cross sections have been produced and are included in Appendix D.

9.1. Topsoil

Topsoil was encountered in PRAIRIE_AUK_BH109 only with a thickness of 0.4m, encountered at the ground surface. The material encountered was described as dark brown sandy topsoil with rootlets.

9.2. Made Ground

Made Ground was encountered in all 31 exploratory locations at the site. The stratum comprised granular and cohesive material.

Granular Made Ground was encountered in all locations except PRAIRIE_AUK_BH109. The material was encountered at ground level with thicknesses between 0.4m and 2.5m. A second layer of granular Made Ground was encountered in ATK_TP_010 at 2.2m depth. The material was typically described as black / brown / grey, sand and gravel / sandy gravel / gravel / clayey sand / with cobbles. The gravel encountered was fine to coarse subangular to subrounded including slag, coal, ash, macadam, concrete, brick, clinker, sandstone and coke. Cobbles are angular and subangular slag, brick and concrete.

The cohesive material was encountered in six locations at depths between 0.4m and 1.8m with thicknesses between 0.4m and 1.2m. The material was typically described as soft to firm brown grey mottled black slightly sandy silty clay with gravel of ash and clinker, and cobbles of brick.

The characteristics for the granular and cohesive fractions of the Made Ground have been discussed separately below.

9.2.1. Classification

Cohesive material

2 No. natural moisture content tests conducted on the cohesive Made Ground samples recorded natural moisture contents ranging from 34.3% to 44.1%, with an average value of 39.2%.

2 No. sets of Atterberg testing for classification were carried out on samples of the cohesive Made Ground which are presented in Figure 1, Appendix E. The Plasticity Index values obtained are 33.0% and 38.0% with an average value of 35.5%. As can be seen from the graph, both samples were classified as high plasticity clay soils. A characteristic design PI value of 40% would be reasonable for design.

9.2.2. Particle size distribution

Granular material

7 No. particle size distribution tests were undertaken within the granular Made Ground as shown in Figure 2, Appendix E. The results suggest a highly variable nature of the material. Based on the mean values of the results, the material can be described as clayey sandy very silty gravel with a medium cobble content.

Cohesive material

2 No. particle size distribution tests were undertaken within the cohesive Made Ground as shown in Figure 3, Appendix E. The results suggest a highly variable nature of the material. Based on the mean values of the results, the material can be described as slightly gravelly slightly sandy clayey silt.

9.2.3. Density

Granular Made Ground

2 No. particle density tests were carried out within the granular Made Ground with values of 2.64 Mg/m^3 and 2.32 Mg/m^3 recorded, giving an average value of 2.48 Mg/m^3.

4 No. laboratory CBR tests were carried out within the granular Made Ground and the initial bulk density values range between 1.78 Mg/m^3 and 2.16 Mg/m^3 with an average value of 1.92 Mg/m^3 (18.8 kN/m^3). The initial dry density was found to be ranging between 1.37 Mg/m^3 and 1.87 Mg/m^3 with an average value of 1.61 Mg/m^3 (15.8 kN/m^3).

BS8004:2015 [30] indicates that the moist unit weight of a clayey sandy very silty gravel can be 14 kN/m^3 to 22 kN/m^3 depending on the density of the stratum.

The average bulk density value obtained from the 4 No. laboratory CBR tests falls within the range indicated in BS8004:2015 [30], therefore, a characteristic bulk density value of 18.8 kN/m^3 would be a reasonable figure for design, but careful consideration would be required due to the variability.

Cohesive Made Ground

1 No. laboratory CBR test was carried out on the cohesive Made Ground material and the initial bulk and dry density values was recorded to be 1.71 Mg/m^3 (16.8 kN/m^3) and 1.16 Mg/m^3 (11.4 kN/m^3).

BS8004:2015 [30] indicates that the moist unit weight of a soft to firm slightly sandy silty clay with gravels and cobbles can be 15kN/m^3 to 20 kN/m^3. The bulk density value obtained from the laboratory CBR test falls within the range.

9.2.4. Effective strength properties

No effective stress laboratory testing was undertaken on the Made Ground. Separate parameters are provided for granular and cohesive soils. However, it is likely that soils will be mixed and judgement will be needed as the basis on the basis of the relative proportions.

Granular Made Ground

An average fine content of 15% was found for the granular Made Ground material, based on the 7 No. particle size distribution tests carried out. The guidance given in BS8004: 2015 [30] recommends deriving the critical friction angle for siliceous sands and gravels with fines content not exceeding 15% based on the following empirical relationship:

$$\phi'_{cv,k} = 30° + \phi'_{ang} + \phi'_{PSD}$$

The gravel was typically described as subangular to subrounded, therefore ϕ'_{ang} is taken as 2°. The uniformity coefficient, C_U, is found to be in the range of 7.5 to 750 with an average value of 211 indicating the material to be very variable. ϕ'_{PSD} is recommended to be 0° to be conservative. $\phi'_{cv,k}$ of the granular Made Ground could therefore be taken as 32° for preliminary design purposes.

Cohesive Made Ground

The guidance given in BS8002: 2015 [31] recommends deriving the critical friction angle based on the following empirical relationship:

$$\phi'_{cv,k} = 42° - 12.5 \log \mathrm{PI}$$

A PI value of 36 % for the cohesive Made Ground correlates to a critical friction angle (ϕ_{cv}) of ~22°.

9.2.5. Undrained shear strength properties

Cohesive Made Ground

In the absence of in-situ or laboratory tests, the undrained shear strength, c_u, of the cohesive Made Ground is assessed based on the material description. The material was typically described as soft to firm, therefore, a c_u value of 40 kPa would be appropriate for preliminary design. Lower values e.g. 20 kPa should be used in areas where the soft material dominates or if there is a need for caution.

9.2.6. Compaction properties

Granular Made Ground

2 No. compaction tests by the 2.5 kg rammer method and 1 No. by 4.5 kg rammer method were undertaken in the granular Made Ground. These tests obtained results for the moisture content and dry density relationship as presented in Figure 4, Appendix E. The optimum moisture content for the re-use of the stratum as fill was found to be between 10.5% and 18.0% with an average value of 14.5%. The maximum dry density achieved was between 1.61 Mg/m^3 and 1.86 Mg/m^3.

Cohesive Made Ground

2 No. compaction tests by the 2.5 kg rammer method were undertaken in the cohesive Made Ground. These tests obtained results for the moisture content and dry density relationship as presented in Figure 5, Appendix E. The optimum moisture content for the re-use of the stratum as fill was found to be 22.0% and 23.5% with an average value of 22.8%. The maximum dry density achieved was 1.54 Mg/m^3 and 1.56 Mg/m^3.

9.2.7. Concrete aggressiveness

Granular Made Ground

A total of 4 No. granular Made Ground samples were tested to BRE SD1 Suite A [32].

To comply with BRE SD1 in a data set where there are only a small number of soil samples for the location, the highest sulphate test results are taken as the characteristic value for water-soluble sulphate (mg/l SO_4). Similarly, the lowest pH values are reported.

The data is presented in Table 9-1. The results classify granular Made Ground (4 no.) as DS-1 / AC-1 according to Table C1 of BRE special Digest 1 [32].However, based on our current understanding the Made Ground material is to be removed and these values are provided for information only.

Table 9-1 - Granular Made Ground Chemical Analysis

Test	Units	Average Value	A small number of Samples	
			Lowest	Highest
pH	-	9.21	8.2	
Sulphate Aqueous Extract as SO_4	mg/l	275.3		427.0

Cohesive Made Ground

Cohesive Made Ground was not tested to BRE SD1 Suite A. The Design Sulphate Class and ACEC classification is assumed to be the same as the granular Made Ground.

9.3. Glaciolacustrine Deposits

Glaciolacustrine Deposits were encountered in all locations where full thickness of the Made Ground was penetrated. The material was encountered at depths between 0.8m and 3.0m below Made Ground. The thicknesses of the deposits decreased from north to south, with values of 12.9m recorded in PRAIRIE_AUK_BH110 at the northern end of the site decreasing to 4.6m recorded in PRAIRIE_AUK_BH109 at the southern end of the site. The material encountered was predominantly cohesive with a laminated nature and variable strength profile. Organic odour was noted locally.

9.3.1. Classification

19 No. sets of Atterberg testing for classification were carried out on samples of the Glaciolacustrine Deposits which are presented in Figure 6, Appendix E. The Plasticity Index values obtained range from 13.0 % to 35.0 % with an average value of 23.2 %. As can be seen from the graph, the samples ranged from low plasticity to high plasticity, with all but 1 sample tested to be clay soils. A characteristic value of PI of 23% may be reasonable for most design purposes, however, consideration should be given to the laminated nature of the material and associated variability of the plasticity.

9.3.2. Particle size distribution

8 No. particle size distribution tests were undertaken within the Glaciolacustrine Deposits as shown in Figure 7, Appendix E. Based on the mean values of the results, the material can be described as slightly gravelly slightly sandy clayey silt.

9.3.3. Density

1 No. particle density test was carried out within the Glaciolacustrine Deposits with a value of 2.57 Mg/m^3 recorded.

10 No. laboratory CBR tests were carried out within the Glaciolacustrine Deposits and the initial bulk density values range between 1.83 Mg/m^3 and 1.99 Mg/m^3 with an average value of 1.94 Mg/m^3 (19.0 kN/m^3). The initial dry density is found to be ranging between 1.37 Mg/m^3 and 1.59 Mg/m^3 with an average value of 1.51 Mg/m^3 (14.8 kN/m^3). A characteristic bulk density value of 1.9. Mg/m^3 is a reasonable value for most preliminary design purposes.

9.3.4. SPT testing

11 No. Standard Penetration Tests were carried out at depths between 2m and 14m bgl, with the SPT 'N' values ranging from 13 to 136 (extrapolated). As presented in Figure 8, Appendix E, an SPT 'N' value of 15 is considered reasonable for most preliminary design purposes.

9.3.5. Effective strength properties

No effective stress laboratory testing was undertaken on the Glaciolacustrine Deposits.

The guidance given in BS8002: 2015 [31] recommends deriving the critical friction angle based on the following empirical relationship:

$$\phi'_{cv,k} = 42 - 12.5 \log \mathrm{PI}$$

Based on the above relationship a PI value of 23.2 % for the Glaciolacustrine Deposits correlates to a critical friction angle (ϕ_{cv}) of 25°.

The relationship plot between peak angle of shearing resistance $\phi'_{p,k}$ and plasticity index from Terzaghi, Peck and Mesri, 1996, indicates a higher $\phi'_{p,k}$ value of approximately 30°. The critical state $\phi'_{cv,k}$ value is therefore considered to be slightly lower than 30°. These values may be considered reasonable based on the higher sand and silt content within the material, however, to account for its organic content and laminated nature, a lower $\phi'_{cv,k}$ value of 25° is considered to be more appropriate for most preliminary design purposes.

9.3.6. Undrained shear strength properties

SPT Derived Undrained Shear Strength

SPT 'N' values were used to estimate the undrained shear strength of the clay by applying the following correlation developed by Stroud & Butler (1975) [33]:

Undrained shear strength, $c_u = f_1 \times N$

Where f_1 is a factor related to plasticity of the clay. For the characteristic plasticity index of Glaciolacustrine Deposits ~23.2%, an f_1 value of 5.1 was considered appropriate to derive c_u. It should be noted that the SPT 'N' values have not been corrected for overburden pressure. SPT test was carried out between 2m and 14m bgl and the N' values range from 13 to 136. The c_u values obtained using this correlation range from 66 – 694 kPa. As presented in Figure 9, Appendix E, an SPT of 15 is typical for the stratum. This would equate to a c_u value of 75 kPa based on an SPT 'N' value. This might be reasonable for deep deposits however, as noted below lower values would be more appropriate in the shallower material.

Hand Shear Vane Data

39 No. hand shear vane tests were undertaken in Glaciolacustrine Deposits at shallower depths of between 1m and 2.8m bgl. The shear strength ranges from 42 kPa to 120 kPa with a mean value of 81 kPa. Plot of undrained shear strength (c_u) from Hand Shear Vane tests against elevation is included in Figure 9, Appendix E.

Triaxial Data

No triaxial tests were carried out on samples taken from Eston Road, however, 4 No. unconsolidated undrained triaxial tests were undertaken on Glaciolacustrine Deposits samples in borehole PRAIRIE_AUK_BH101 which is located approximately 80m north of Eston Road site. The samples were obtained from reduced level of between 5.6m AOD and -2.4m AOD. The undrained shear strength ranges from 26 kPa to 125 kPa.

Based on the exploratory holes located within the Eston Road site, the undrained shear strength values obtained from the SPT data are consistent to those obtained from the Hand Shear Vane tests. The values obtained from the triaxial tests on PRAIRIE_AUK_BH101 samples, however, are significantly lower. Considering the location of PRAIRIE_AUK_BH101 being 80m away from the site, the 4 No. triaxial test results are therefore not regarded as relevant to the site.

Undrained shear strength

It can be seen that the undrained shear strength of the Glaciolacustrine Deposits at the site was variable. The material at shallower depth was generally described as soft and firm which is consistent with the lower undrained shear strength values obtained from the hand shear vane tests. The near surface material is important for the design as it forms the foundation of the proposed road and an undrained shear strength of 40 kPa is considered to be a moderately safe value for preliminary design purposes.

9.3.7. Compaction properties

2 No. compaction tests by the 2.5kg rammer method were undertaken in the Glaciolacustrine Deposits. These tests obtained results for the moisture content and dry density relationship as presented in Figure 10, Appendix E. The optimum moisture content for the re-use of the stratum as fill was found to be 20% and 22% with an average value of 21%. The maximum dry density achieved was 1.61 Mg/m^3 and 1.55 Mg/m^3.

9.3.8. Concrete aggressiveness

A total of 9 No. Glaciolacustrine Deposits samples were tested to BRE SD1 Suite A (Greenfield site pyrite absent).

To comply with BRE SD1 in a data set where there are five to nine results available for the location, the mean of the highest two of the sulphate test results are taken as the characteristic value for water-soluble sulphate (mg/l SO4). Similarly, the mean of the lowest two pH values are reported.

The data is presented in Table 9-1. The results classify Glaciolacustrine Deposits (9 No.) as DS-2 / AC-2 according to Table C1 of BRE special Digest 1 [32]. Due to the low number of tests it is recommended that consideration is also given to STDC site wide values before specifying concrete classes.

Table 9-2 - Glaciolacustrine Deposits Chemical Analysis

Test	Units	Average Value	5- 9 Samples	
			Mean of the lowest 2	Mean of the highest 2
pH		8.0	6.2	
Sulphate Aqueous Extract as SO_4	mg/l	289.7		969.3

9.4. Redcar Mudstone Formation

Underlying the superficial deposits, Redcar Mudstone Formation was encountered in PRAIRIE_AUK_BH109 only at 5.8m bgl. The material was described as weak to medium strong dark blue grey mudstone distinctly weathered locally destructured, and medium strong light grey siltstone unweathered locally partially weathered. PRAIRIE_AUK_BH109 terminated at 0.29m AOD without fully penetrating the stratum.

9.4.1. Density

2 No. Unconfined Compressive Strength tests were carried out on samples of the Redcar Mudstone Formation, and the bulk density values range between 2.58 Mg/m^3 and 2.60 Mg/m^3 with an average value of 2.59 Mg/m^3 (25.4 kN/m^3). The dry density was found to be ranging between 2.51 Mg/m^3 and 2.54 Mg/m^3 with an average value of 2.53 Mg/m^3 (24.8 kN/m^3).

9.4.2. Strength characteristics

1No. Point Load test was carried out on a sample of the 'weak locally medium strong dark blue grey mudstone' taken at 7.7m bgl. The point load index, $I_{s(50)}$, was found to be 0.078 MPa. Tomlinson [33] indicated the available relationships between uniaxial compression strength, q_c, and point load strength for Mudstone/siltstone (Coal Measures) to be $q_c/ I_{s(50)}$ = 23, therefore, the unconfined compressive strength is found to be1.79 MPa. The strength value obtained is lower than the 'weak' rock strength of 5 to 25 MPa [34] as might be derived from exploratory hole logs.

2 No. Unconfined Compressive Strength tests were carried out on samples of the 'medium strong light grey siltstone' taken at 9.0m bgl and 11.3m bgl. The failure loads were 105.9 kN and 132.2 kN, and the unconfined compressive strength values were found to be 20.2 MPa and 24.4 MPa (average 22.3 MPa). The strength value obtained is lower than the 'medium strong' rock strength of 25 to 50 MPa [34].

It can therefore be confirmed that the stratum is of variable strength which increases with depth. The mudstone is proven to be more competent compared to the overlying superficial deposits. With its top elevation encountered some 5.8m below ground level, the stratum is not considered likely to affect the proposed road construction.

9.5. Penarth Group

The Penarth Group was anticipated to underly the Redcar Mudstone Formation. Since the full thickness of the Redcar Mudstone Formation was not penetrated in PRAIRIE_AUK_BH109, the Penarth Group was not encountered in the ground investigation.

9.6. Mercia Mudstone Group

Mercia Mudstone Group was encountered within PRAIRIE_AUK_BH107, PRAIRIE_AUK_BH108 and PRAIRIE_AUK_BH110 underlying the superficial deposits. The material was typically described as extremely weak to strong red brown mudstone partially weathered, locally destructured, with many interbeds of gypsum. The top elevation of the stratum increased from -6.6m AOD at the northern extent of the site (PRAIRIE_AUK_BH110) to 1.46m AOD at the centre of the site, and was expected to decrease southwards as the stratum was anticipated to underly the Redcar Mudstone Formation and the Penarth Group. Since the full thickness of the Redcar Mudstone Formation was not penetrated in PRAIRIE_AUK_BH109, Mercia Mudstone Group was not encountered at the southern part of the site.

Gypsum is a soluble material which can present a hazard. It is recommended that further assessment is carried out using site wide data to ascertain the degree of risk.

9.7. Summary

The characteristic geotechnical parameters derived as part of this section that are relevant to the proposed works are summarised in Table 9-3 below.

Table 9-3 - Summary of relevant geotechnical parameters

Material	Unit weight (kN/m³)		Critical friction angle (°)	Effective cohesion (kPa)	Undrained shear strength (kPa)	UCS (MPa)	Design sulphate class /ACEC
	γ_d	γ_b	$\phi'_{cv,k}$	c'_k	c_u	q_{uc}	-
Granular Made Ground	15.8	18.8	32	-	-	-	STDC site wide value recommended
Cohesive Made Ground	16.8	11.4	22	0	20 – 40	-	STDC site wide value recommended
Glaciolacustrine Deposit	14.8	19.0	25	1	40	-	STDC site wide value recommended

10. Geotechnical Risk Register

This section presents the Geotechnical Risk Register for the proposed works to be undertaken for the scheme. The Geotechnical Risk Register identifies the risks and the consequences, recommends preventative or mitigation measures and re-assesses the risk in light of those measures. The geotechnical risks are discussed in terms of probability, severity and risk, as defined below:

Probability (P): The perceived likelihood of the identified geotechnical hazard actually occurring (defined as a rating in Table 10-1).

Severity (S): The perceived impact, in terms of safety, financial, temporal, legal, or operational consequence, of the occurrence of the identified geotechnical hazard on the identified receptor(s) (defined as a rating in Table 10-2).

Risk(R): The perceived level of concern which should be assigned to the identified hazard, based on the probability of occurrence, and taking into due account the perceived severity of impact and consequence on the receptor(s) (defined as a risk number in Table 10-3).

The Geotechnical Risk Register and terminology adopted for this project is based on the Highways Agency guidance (HD22/08, 2008). It is a semi-quantitative assessment based on engineering judgement. The classification of probability and severity used in this Geotechnical Risk Register is presented in Table 10-1 and Table 10-2 respectively.

The risk classification is based on:

Risk = Probability Rating x Severity Rating

The explanation of risk number is given in Table 10-3 which gives the assessed risk level and appropriate actions.

Table 10-1 - Assessment of probability

Rating	Likelihood (Class Descriptor)	Class Description
4	>85%	Highly likely
3	25 – 84%	Likely (regular occurrence)
2	2 – 25%	Fairly unlikely
1	<1%	Very unlikely to occur

Table 10-2 - Assessment of consequence / severity

Rating	Class Descriptor	Construction Impact	Operation / Maintenance Impact	Environmental Impact
4	Disastrous	Construction unsustainable	Scheme operation unsustainable/deaths & serious injury	Major environmental incident – Threat to public health or safety
3	Substantial	Significantly increased construction costs & operational difficulty	Increased scheme costs Injury / Illness	Environmental incident triggers damage &/or nuisance prosecution and/or compensation
2	Significant	Impact to costs/programme	Effect on scheme costs	Third party environmental impact requiring management response to recover
1	Marginal	Impact to programme	Small effect on scheme costs	Any environmental impact regarded as significant.

Table 10-3 - Perceived risk level and mitigation action

Risk Number	Perceived Risk Level	Action Required
13 to 16	Intolerable	Eliminate Risk
9 to 12	Unacceptable (avoid)	Avoid or transfer risk
5 to 8	Unacceptable (manage)	Risk managed by prevention or mitigation
1 to 4	Negligible	Could be ignored

A summary of the potential geotechnical risks identified at this stage are detailed in Table 10-4. The Geotechnical Risk Register will be updated as the design of the scheme progresses to take into consideration any additional information obtained.

Table 10-4 - Geotechnical risk register

Hazard	Consequence	Risk Rating			Recommended Mitigation Measures	Revised Risk Rating		
		P	S	R		P	S	R
Incompetent Made Ground material being left in-situ	Excessive differential settlement due to poorly compacted in-situ Made Ground material resulting in an uneven road surface. Safety risk to drivers. Volume expansion beneath the pavement resulting in uneven road surfaces and damage to road construction. Safety risks to drivers. Additional cost and time required for extensive remedial works. The use of steel slag as a founding material is not compliant with the Tees Valley Design Guide. So a further consequence would be that the road may not be adopted.	3	3	9	Recommended mitigation measure is complete removal of Made Ground and replacement with inert slag-free material. This will require some areas of locations where the depth of excavation exceeds 2.5m. The revised risk rating is given on the basis that this action is taken. If complete removal of Made Ground material is not to be carried out then a departure from the Tees Valley Design Guide would need to be agreed with Redcar and Cleveland B.C. There is no clear reason why they would agree to this but it may be possible to make a case. Site wide testing information on the composition and behaviour of the slag would be a reasonable basis for considering the potential for leaving in. It would be wise to explore further with Redcar and Cleveland before progressing.	1	3	3
Differential settlement at the interface between the existing and widened pavement	Excessive differential settlement between the existing and widened pavement resulting in an uneven road surface. Safety risk to drivers. Future remedial works	3	3	9	Soft spot to be removed at formation level. The soft clay material of the Glaciolacustrine Deposits at near surface depth to be removed. Consider a hold period between constructing new fill and placing the road surface. The duration of the hold period could be estimated or based on survey monitoring to confirm the absence of movement.	1	3	3

Hazard	Consequence	Risk Rating			Recommended Mitigation Measures	Revised Risk Rating		
		P	S	R		P	S	R
Excessive settlement of culvert crossing caused by soft material within Glaciolacustrine Deposits	Settlement of culvert crossing due to less competent ground conditions. Alternatively, the adjacent ground could settle relative to the culvert. Re-design with delays to programme and increase in cost. Additional cost and time required for extensive remedial works.	3	3	9	Careful design of culvert and adjacent ground. Piled foundations may not be required but the following will be required as a minimum. Any soft clay material of the Glaciolacustrine Deposits at near surface depth to be removed, beneath the culvert and adjacent ground. Appropriate hold period to be adopted to confirm the absence of differential settlement before road construction. Survey points to be utilised to monitor and confirm the absence of settlement near culvert crossing.	1	3	3
Uncertainty in groundwater regime	Higher than anticipated groundwater level may cause poor sub-grade conditions. Drainage design may need to change, and this could delay works. May adversely affect stability of excavations and slopes.	2	3	6	Available GI data, including GI from outside the site to be used to ascertain the groundwater regime. Design accordingly.	1	3	3
Striking unexploded ordnance (UXO)	Injury or fatality of personnel and members of the public. Extensive remediation works may be required causing scheme delay and increased cost.	3	4	12	Preliminary Zetica UXO Risk assessment indicates a moderate risk at the site. Arcadis to be consulted for site wide recommendations and if further mitigation is required.	3	4	12
Soft sub-grade beneath made ground	Soft natural ground has been identified beneath the made ground. This will not be suitable as a founding material for road construction. If left in place it could result in the road not being adopted by Redcar and Cleveland and or poor road performance.	3	3	9	Remove soft material prior to filling.	1	3	3

Hazard	Consequence	Risk Rating			Recommended Mitigation Measures	Revised Risk Rating		
		P	S	R		P	S	R
Encountering buried structure / underground void	Carriageway subsidence / collapse or differential settlement due to unsuitable treatment of buried structures or voids. Safety risk to drivers.	3	3	9	Use record drawings and or historical data to identify historical structures. Remove structures or treat them such that they will not adversely affect the highway construction. Inspect site following removal of made ground to check for presence of uncharted / unexpected structures. All voids to be backfilled with appropriate fill material and compacted in accordance with the specification. The risk from buried structure could be eliminated if all buried structures are removed completely however this may not be practical. As an alternative it may be reasonable to remove structures to a specific level beneath the new construction. Structures which pose a risk of future collapse are to be removed.	1	3	3

11. Conclusions and Recommendations

11.1.1. Summary of works

The proposed enabling works include a roundabout and upgrading the two existing western and southern road spurs which include the existing Eston Road alignment for 200m south towards the junction with the A66 and to the west into Middlesbrough Road East. These works include opening the culvert carrying the adjacent Holme Beck water course and adding a combined use cycle/footpath. The design of the culvert crossings is outside the scope of this report.

11.1.2. Geotechnical

The main aims of the geotechnical work at the site is to ensure a suitable road construction and where practicable to meet the requirements of the Redcar and Cleveland guidance so that the road can be adopted by Redcar and Cleveland in the future. A number of areas where particular consideration is required to help achieve these aims are discussed further below.

11.1.2.1. Extensive Made Ground

It is understood that the general proposal for the whole of the Prairie site is to remove the top 2.5m thickness of Made Ground, as per the Grangetown Prairie Area Remediation Options Appraisal and Enabling Earthworks and Remediation Strategy Report [12]. On the basis that Made Ground is found to be slightly deeper than 2.5m locally, however, it is recommended that the full depth of the Made Ground material is removed beneath the road and associated earthworks. The advantage of this is to remove all slag materials from the site. This would be a simple way to eliminate the risk of potential future problems of road surface irregularity associated with slag expansion and is likely to make the adoption more straightforward. The typical thickness of the Made Ground is 1.6m, however, based on the findings from the Ground Investigation works, locally Made Ground material was encountered up to a maximum depth of 3.5m without the stratum being fully penetrated. Details of the Made Ground thicknesses are provided in Appendix D.

11.1.2.2. Soft ground conditions

It is understood that the Remediation Strategy Report [12] proposed to remove all made ground except where it is more than 2.5m thick. The ground investigation indicates that Glaciolacustrine Deposits are present beneath the made ground. The upper portion of this material tends to be soft and will be unsuitable foundation for a road. This soft unsuitable zone is generally less than 1.0m thick and it is recommended that this material is removed to a depth where firm ground is encountered.

It is recommended that the firm ground is proven by in-situ testing. This could comprise proof rolling and testing with a shear vane or a dynamic probe. The requirement will be detailed in the Earthwork Specification. However, it is anticipated that hand shear vane test result of 50 kPa in the cohesive material, and CBR value of 2.5 obtained using a dynamic probe would indicate a suitable sub-grade.

11.1.2.3. Remains of historical buried structures.

It is proposed in the Remediation Strategy Report [12] that the remains of historical foundations are removed to 2.5m below existing ground level. If foundations extend deeper than 2.5m, it is recommended that this is reported to Atkins and the approach is decided on a site-specific basis. Depending on the depth and position of the underground structure, it might not always be necessary to remove the structure. The decision will be based on an assessment of the potential for a local hard spot to cause surface deformation in the future.

This assessment will consider the nature of the hard spot and also the strength of the ground surrounding the buried structure. Subject to programming of the works, it might be possible to use a hold-period to ensure that any differential settlement around the hard spots has occurred prior to surfacing of the carriageway takes place.

It is proposed that following the stripping of made ground a visual inspection is undertaken to check for the presence of made ground. As a further check historical plans should be used to identify the positions of old construction and in the event that these are not encountered during the strip then consideration should be given to trial pitting to check their presence. If the above techniques, do not provide clear evidence that buried objects have been removed then consideration should be given to geophysics. However, it is not expected that this will be necessary if all made ground is stripped.

11.1.2.4. The Holme Beck channel

Careful consideration should be given to the gradient of the side slope of the Holme Beck channel. It is particularly important at areas where the channel is adjacent to the road as failure of the slope will impact on the road. The slope gradient should be designed on the basis of slope stability analysis depending on the strength of the in-situ material and the proximity of the watercourse to the road. It is anticipated that the channel will be formed with a combination of in-situ Glaciolacustrine Deposits and fill material. Based on experience, the side slope formed in natural Glaciolacustrine Deposits should be constructed with a maximum slope gradient of 1 in 3. A steeper slope is likely to be formed using imported Made Ground fill material.

11.1.2.5. Ground conditions at proposed culvert locations

There are two proposed box culvert crossings associated with Holme Beck passing under the eastern spur adjacent to the roundabout and further north passing under the turning point at the terminal of the northern spur. Based on the findings from the nearby trial pits, the existing ground comprises granular Made Ground of 1.1m to 1.7m thickness overlying Glaciolacustrine Deposits with its upper layer of 0.6m to 1.1m thickness typically described as soft, and underlain by more competent firm to stiff material. Mercia Mudstone Formation was encountered at 8.7m bgl (1.5m AOD) and 14.4m bgl (-6.6m AOD) based on the nearby deeper boreholes PRAIRIE_AUK_BH107 20m east of the eastern culvert, and PRAIRIE_AUK_BH110 110m north of the northern culvert. Subject to details of the proposed culverts, the local ground after remediation, with the Made Ground and soft upper layer of Glaciolacustrine Deposits removed, is expected to be a suitable culvert foundation material for a spread footing. However, careful consideration should be given to the isolated soft to firm band of Glaciolacustrine Deposits encountered between 5.0m bgl and 7.5m bgl within PRAIRIE_AUK_BH110 which might indicate that piled foundation to be more favourable for the northern culvert.

11.1.2.6. Excavation and dewatering

Groundwater strikes recorded groundwater at depths between 0.6m and 3.5m bgl within the Made Ground or Made Ground/Glaciolacustrine Deposits interface. Therefore, it is considered quite likely that groundwater control will be required for foundation excavations.

11.1.3. Contaminated Land

Extensive Made Ground comprising slag was present across the site. Two exceedances for naphthalene and arsenic were recorded above GAC for a commercial and end use. Given the proposed enabling works, there is anticipated to be extensive cover of hardstanding and this is likely to reduce risks to human receptors on site. Assuming the use of robust risk assessment and method statements during construction, there is limited potential for exposure of construction workers to the underlying soils.

Asbestos screening in the laboratory was undertaken on 13 samples; all of which were within the top 1.50 m of material collected with 12 samples obtained from Made Ground and one sample collected from natural soils. Asbestos was detected above detection limits in four samples sent for screening. The risks from asbestos will need to be further assessed as part of the construction works by a suitably qualified and experienced asbestos specialist. Extensive hardstanding cover is likely to minimise risk to future human health receptors.

A total of 13 soil samples were tested for their leachability of contaminants. Several exceedances of metals, inorganics and organics have been recorded against WQS. Exceedances were generally the same order of magnitude above EQS (both freshwater and transitional) for metals and inorganics. Exceedances were generally recorded in Made Ground.

Exceedances of PAHs are recorded up to a maximum of five orders of magnitude above the freshwater EQS. Whilst laboratory leachate testing is generally more aggressive than in-situ conditions and may not be representative of actual leaching conditions, potentially overestimating the concentrations, it is expected there is an on-site source of contamination. The sites industrial legacy, constituents including a high slag content within the Made Ground, are widespread across the site. Considering the proximity of the Holme Beck to the proposed development and the elevated concentrations of PAHs recorded, there is likely to be a potentially unacceptable risk to the Holme Beck depending on the current condition of the culvert.

Considering the distance of the River Tees from the site and the low permeability soil and rock deposits at the site it is expected that the potential for migration will be low and therefore, there is likely to be a low risk to the River Tees.

Exceedances of soil leachate samples above the DWS were recorded between one and three orders of magnitude greater than the DWS. There is unlikely to be a potentially unacceptable risk to the Secondary A (off-site) and Secondary B Aquifers due to an absence of groundwater abstractions, groundwater not likely to be utilised in the wider area for drinking water due to areas historical legacy and impermeable deposits preventing vertical and lateral migration.

Remediation using capping insitu is proposed for the wider site area to include turnover of Made Ground up to 2.50 m in depth. This is to include removal of relic structures, environmental contamination removal and treatment, and replacement with treated material to create a suitable development platform. However, at the time of writing this report, this remediation had not been completed but it is expected that remediation will be undertaken on site by Seymour Civil Engineering and overseen by Arcadis prior to the commencement of the highway construction works. Once this work is complete, this should mitigate additional risks to Holme Beck by capping and / or removing part of the source.

Analytical results from 26 soil samples tested as part of the Atkins investigation were uploaded into CAT-WASTE Soil. Four samples were recorded as hazardous waste at locations PRAIRIE_AUK_TP162_SO_0170, PRAIRIE_AUK_TP157_SO_0080, PRAIRIE_AUK_TP182_SO_0090 and ATK_TP_011_0090, all remaining samples were classified as non-hazardous.

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Appendices

Appendix A. Site Location Plans and Drawings

A.1. Site Location Plan

A.2. Former Prairie Site Layout

Appendix B. Ground Investigation Factual Reports

B.1. Prairie Site Ground Investigation Works Final Factual Report (Rev.01)

B.2. Eston Road Intrusive Works Final Factual Report (Rev.00)

Appendix C. Screening sheets

Appendix D. Geological cross sections

D.1. Eston Road Section Line Plan

D.2. Eston Road Section Line 1 – North to South

D.3. Eston Road Section Line 2 – West to East

Appendix E. Geotechnical Data Plots

Appendix F. CATWASTE Data

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