Norwich Western Link

Environmental Statement

Chapter 13: Geology & Soils

Appendix 13.2: Generic Quantitative Risk Assessment

Author: WSP UK Limited

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1 Introduction

1.1 Authorisation

1.1.1 WSP was instructed by Norfolk County Council (the Client) to undertake an assessment of the contaminated land risk liabilities and constraints associated with the development of the proposed Norwich Western Link (the Proposed Scheme) Road (the Site).

1.1.2 A Site location plan and layout plan is provided in **Appendix A**.

1.2 Proposed scheme

1.2.1 The Proposed Scheme comprises of approximately 6 kilometres of dual carriageway from the Broadland Northway (A1270) (formerly Norwich Northern Distributor Road) / Fakenham Road (A1067) intersection at the northern extents of the scheme, to the A47 at the southern extents of the scheme.

1.2.2 It was concluded in the recent Ground Investigation Report and confirmed by Norwich County Council (NCC) that the preferred route for the scheme was Option C for the route alignment. The route alignment at the time of writing this report has been included within **Appendix A.**

1.2.3 The Proposed Scheme extends across the River Wensum flood plain to the north and the River Tud valley to the south. The route passes through farmland and woodland, crossing country lanes and roads within the local network. The Proposed Scheme will pass through sections of cutting and embankment, as well as incorporating a number of road overpasses and underpasses, wildlife crossings and pedestrian footbridges.

1.2.4 One key feature of the scheme will be the approach to the proposed 89junction with the A1067, where it is proposed the alignment will cross the River Wensum by a viaduct. The viaduct will span over the river valley wetlands.

1.3 Objectives

1.3.1 The key objectives of this report comprise:

- Summarise the findings of the ground investigation and ground conditions identified across the Site;
- Refine the conceptual site model developed in the Interpretive Environmental Desk Study Report (undertaken by WSP) for the Site and identify potential constraints with respect to contaminated land which may impact the proposed scheme; and
- Consider the resulting implications of these in terms of the associated environmental requirements, risks and liabilities.

1.4 Scope of works

1.4.1 In order to meet the objectives detailed in **Section 1.3**, the scope of works for the investigation comprised:

- Site investigations undertaken in phases between 20 August 2019 to 8 November 2019 and 17th August 2020 to 22 September 2020;
- Laboratory analysis of recovered soil and groundwater samples;
- Refinement of the preliminary Conceptual Site Model (CSM) that was developed in the Interpretive Environmental Desk Study Report;
- Generic Quantitative Risk Assessment (GQRA) of potentially sensitive receptors with respect to contamination; and
- Provision of recommendations with respect to the management and mitigation of potential ground contamination constraints or liabilities which are identified.

1.5 Legislative context and guidance

1.5.1 The assessment was undertaken in the legislative context of:

- Part 2A of The Environmental Protection Act (1990); and
- National Planning Policy Framework (2021).

1.5.2 The following good practice and statutory guidance was considered, and the assessment was undertaken in general accordance with:

- Environment Agency ('Land Contamination Risk Assessment, LCRM (2021);
- NHBC 'Guidance for the Safe Development of Housing on Land Affected by Contamination', R&D66 (2008);
- CIRIA 'Assessing Risks Posed by Hazardous Ground Gases to Buildings', C665 (2007);
- British Standard 'Investigation of Potentially Contaminated Sites – Code of Practice', BS EN 10175:2011 + A2:2017;
- Defra 'Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance', PB13735 (2012);
- British Standard 'Guidance on Ground Investigations for Ground Gad – Permanent Gases and Volatile Organic Compounds (VOCs)' BS8576:2013; and
- British Standard 'Code of Practice for Ground Investigations', BS 5930:2015.

1.6 Sources of information

1.6.1 **Table 1-1** presents the relevant sources of information which were used in the production of this report.

Table 1-1 Sources of information

Source	Title
WSP Reports	• WSP: NCCT41793-04-B-06-02; Interpretative Environmental Desk Study Report; Norwich Western Link; Norfolk County Council (June 2020)
Third Party Reports	• WSP: 70061370; Norwich Western Link; Factual Report; October 2020 • WSP: 70061370-WSP-RP-GEO-0002 - Norwich Western Link; Ground Investigation Report; October 2020
Public Information	• Google Earth accessed on 15 June 2021; • British Geological Survey (BGS) Online Viewer accessed 15 June 2021; • British Geological Survey (BGS) sheet 147 of Aylesham (1:50,000 Bedrock and Superficial Deposits) and sheet 161 of Norwich (1:50,000 Solid and Drift edition). • Flood Maps for Planning Service (https://flood-map-for-planning.service.gov.uk/), accessed 31 October 2019; • Defra's Multi-Agency Geographic Information for the Countryside (MAGIC) website (https://magic.defra.gov.uk/MagicMap.aspx), accessed 31 October 2019; • Environment Agencies Catchment Data Explorer (https://environment.data.gov.uk/catchment-planning/), accessed 31 October 2019; The report contains British Geological Survey materials ©NERC 2020 and Environment Agency information ©Environment Agency and database right.

1.7 Confidentiality and limitations

1.7.1 This report is addressed to and may be relied upon by Norfolk County Council. The report may not be relied upon or transferred to any other parties without the express written authorisation of WSP. This report should be read in full. No responsibility will be accepted where this report is used, either in its entirety or in part by any other party.

1.7.2 Third party information used in the production of this report has been taken in good faith as being accurate. WSP cannot and will not accept any liability for errors and / or omissions in data provided by others and WSP cannot warrant the work of others.

1.7.3 General limitations of the assessment are included in **Appendix B.**

2 Summary of Site Information

2.1 Site Location and Description

2.1.1 Site location and layout plans are presented in **Appendix A.**

2.1.2 A detailed description of the current land use is provided in the Interpretive Environmental Desk Study Report and summarised below.

Site Location, Description and Current Use

2.1.3 The Site is located to the north-west of Norwich, known as the Norwich Western Quadrant (NWQ). The broad Site area includes the key radial routes of the A47 trunk road, the A1074 (Dereham Road), and the A1067 (Drayton High Road / Fakenham Road).

2.1.4 The Site area encompasses the western fringe of Norwich and settlements, from Lyng, North Tuddenham and Hockering in the west to Horsford, Drayton, Costessey and Bawburgh in the east and all the settlements in between.

Surrounding Area

2.1.5 The surrounding area is predominantly agricultural or wooded land with occasional residential properties and farm buildings. Multiple villages are also present within the vicinity of the Site: Attlebridge to the north; Ringland to the east; Honingham to the south; and Weston Green and Weston Longville to the west. The Weston Green solar farm also lies to the west. The River Wensum and associated flood plain roughly runs from north-west to south-east crossing the Site in the northern section. Further afield to the east lie more densely populated residential areas on the western fringe of Norwich.

2.2 Site History

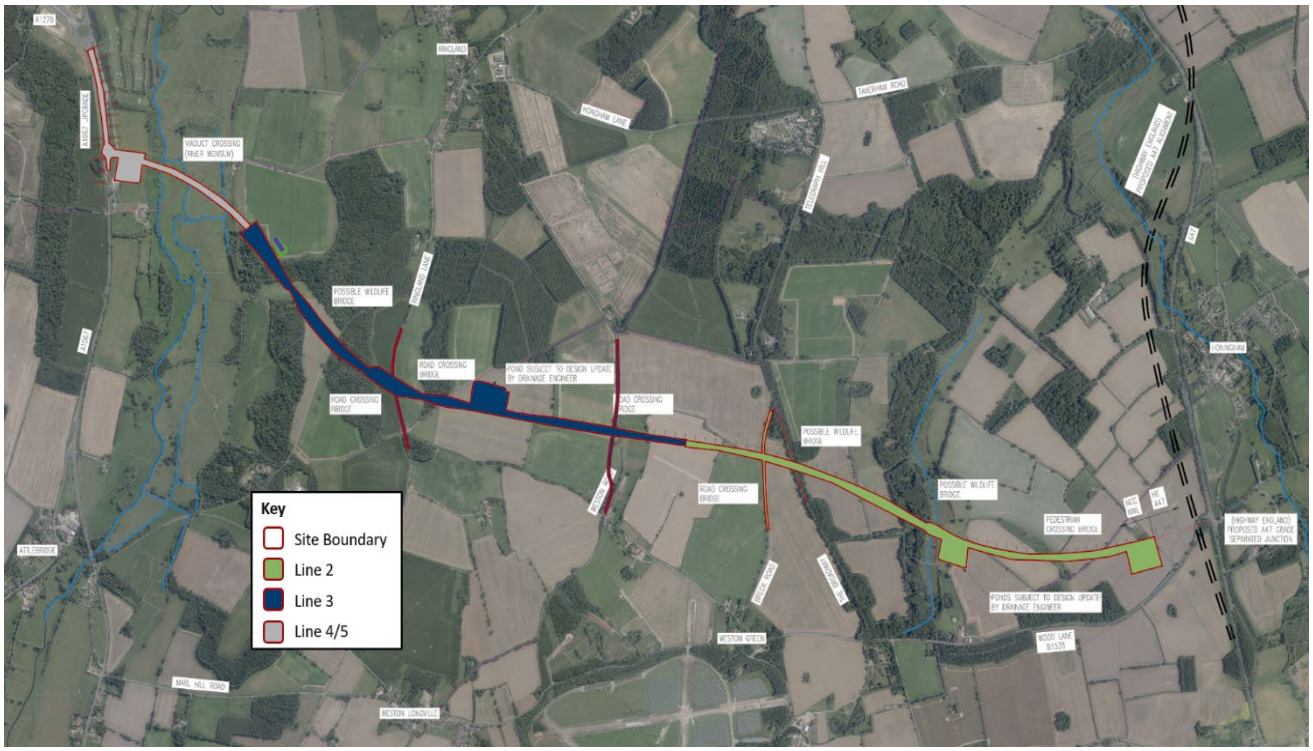
2.2.1 A comprehensive summary of the history of the Site and surrounding area is presented in **Appendix 13.1 Interpretive Environmental Desk Study Report** (Document Reference: 3.13.01).

2.2.2 Mapping from ca. 1882-1884 suggest that the Site comprised multiple agricultural fields and is crossed by multiple roads / tracks. Throughout the 20th century, the area has stayed relatively unchanged. There are multiple marl and clay pits in close proximity that have been infilled in the 1970s.

2.3 Historical Land Use

2.3.1 Historical maps were obtained as part of the Envirocheck reports in the Interpretive Environmental Desk Study Report and were reviewed to identify potentially contaminative former land uses on Site and within a 250m radius of the Site boundary. In order to present the on-Site and off-Site history, the Site has been divided into three sections as indicated on **Figure 2-1** below:

Figure 2-1 Site Boundary



2.3.2 A summary of the on-Site and off-Site features are presented in **Table 2-1, Table 2-2** and **Table 2-3**. Only pertinent features in relation to potential contaminating land uses / sources have been included in the summary tables.

Table 2-1 Summary of Historical Land Uses in Line 2

Historical map (date and scale)	On-site feature	Off-site feature
1883-1885 (1:10,560) 1883-1884 (1:10,560) 1882 (1:2,500) 1906 (1:2,500) 1907 (1:10,560)	Site generally comprises multiple undeveloped fields. In the north, the Foxburrow Plantation with an associated track transects the Site.	An unnamed road runs approximately 60m to the south of Site running in a north-west to south-east orientation. An unnamed road connecting to the unnamed road to the south runs approximately 30m to the west of Site. An Old Marl Pit is located 185m north-west of Site. An Old Clay Pit is located 193m north-west of Site. There are multiple ponds located within 250m of Site in all directions.
1952 (1:10,560) 1957 – 1959 (1:10,000)	No significant change.	The Old Marl and Clay Pits are now unnamed and covered in vegetation.

Historical map (date and scale)	On-site feature	Off-site feature
1971 (1:2,500) 1971 – 1981 (1:2,500) 1976 (1:10,000) 1982 (1:10,000)	A junction, which now crosses the Site in the south, has been altered connecting Wood Lane to the west with the A27 to the south.	Old Marl Pit is no longer shown, presumed infilled. Old Clay Pit is no longer shown, presumed infilled. Buildings (including Berry Hall Cottages and Merrywood House) associated with Honingham are located approximately 250m to the south-west of Site.
1994 (1:2,500) 1999 (1:2,500) 2000 (1:10,000) 2006 (1:10,000) 2019 (1:10,000)	'Robin's Nursery' extends over the Site in the northern section, making up part of the Foxburrow Plantation.	No significant change.

Table 2-2 Summary of Historical Land Uses in Line 3

Historical map (date and scale)	On-site feature	Off-site feature
1883 – 1884 (1:10,560) 1882 (1:2,500) 1905 – 1906 (1:2,500) 1906 (1:2,500) 1907 – 1908 (1:10,560)	Site generally comprises multiple undeveloped fields. Transecting the Site is the Gravelpit plantation with a track running from north to south, the Primrose plantation with associated tracks, the Long plantation and the Rose Carr plantation / nursery in the east. Longrow Lane and an additional unnamed road cross the Site both running from north-west to south-east. The north-easternmost section of Site lies in the flood plains of the River Wensum.	Low farm is located approximately 100m south. A Marl Pit is situated 134m north of Site. An unnamed pond is located approximately 150m north-west of the south-western area of Line 3. The River Wensum is situated approximately 220m east of the north-eastern section of Line 3.
1938 (1:10,560) 1938-1952 (1:10,560) 1957 (1:10,560) 1957 – 1959 (1:10,560)	No significant change.	Marl Pit is now unnamed and covered in vegetation.

Historical map (date and scale)	On-site feature	Off-site feature
1970 – 1971 (1:2,500) 1971 (1:2,500) 1974 – 1975 (1:2,500) 1973 – 1976 (1:10,560) 1975 – 1976 (1:10,560)	Longrow Lane has been changed to Ringland Lane.	Gravel pit plantation adjacent to the central section of Site has reduced in size. A pond associated with the Rose Carr plantation is situated 70m north of Site. Marl Pit is no longer shown, presumed infilled.
1994 (1:2,500)	No significant change.	No significant change.
1999 Aerial Photography (1:2,500) 2000 (1:10,000) 2006 (1:10,000) 2019 (1:10,000)	No significant change.	The pond associated with the Rose Carr plantation has reduced in size.

Table 2-3 Summary of Historical Land Uses in Line 4/5

Historical map (date and scale)	On-site feature	Off-site feature
1882 (1:2,500) 1883 – 1884 (1:10,560) 1906 (1:2,500) 1907 – 1908 (1:10,560)	The Site generally made up of the flood plains of the River Wensum. The River Wensum also transects Site, running in an approximate north-west to south-east orientation. A track is present running in an approximate north-west to south-east orientation. Crooked Oaks plantation with an associated track is also situated in the eastern tip of Site. A Marl Pit extends on to the northern part of the Site (Line 5).	An unnamed road runs from north-west to south-east adjacent to the south of Site. A Marl Pit is located approximately 20m north of Site. Attlebridge Hall is located adjacent to the River Wensum, approximately 150m north of Site The Attlebridge Hills plantation is located approximately 150m north-east of Site.
1938 (1:10,560) 1957 (1:10,000)	The Marl Pit extending on to the Site is unnamed and covered in vegetation.	Marl Pit to the north is now unnamed and covered in vegetation.
1970 (1:2,500) 1975 (1:10,000) 1975 – 1976 (1:10,000)	The layout of the track is detailed as the A1067.	Marl Pit is no longer shown, presumed infilled.

Historical map (date and scale)	On-site feature	Off-site feature
1994 (1:2,500) 1999 Aerial Photography (1:2,500) 2000 (1:10,000) 2006 (1:10,000)	A1067 which crosses part of the Site and runs adjacent to the south of Site is now detailed as Fakenham Road.	No significant change.
2019 (1:10,000)	No significant change.	A roundabout has been constructed on A1067 to the east of Line 5 connecting to the Broadland Northway to the east of Site. Attlebridge Hall to the north of Site is now renamed as Old Hall Cottages. The eastern boundary of the Wensum Valley Hotel Golf and Country Club is located adjacent and south-east of Site.

2.4 Geology

2.4.1 The British Geological Survey (BGS) map of Aylsham (Sheet 147 Bedrock and Superficial Deposits) and Norwich (Sheet 161 Solid and Drift Edition), BGS boreholes (in close proximity to the route alignment) and Geology of Britain online viewer were reviewed. **Table 2-4** summarises the geology underlying the Site.

Table 2-4 Summary of Geology

Aquifer	Strata	Top of stratum (m)	Bottom of stratum (m)	Thickness (m)	Distribution across the site
Not applicable	Surfacing	Ground Level	0.6	0.2 - 0.6	Unit is present across the site and mainly comprised reworked topsoil
Not applicable	Made Ground	Ground level	0.9	1.2	This unit is present in the north of the site adjacent to Fakenham Road.
Superficial	Alluvium	1.2	2	0.8	The unit is present in a band in the north of the Site in the vicinity of the A1067.

Aquifer	Strata	Top of stratum (m)	Bottom of stratum (m)	Thickness (m)	Distribution across the site
Superficial	Head Deposits	Not encountered	Not encountered	Not encountered	The unit is present to the south of the Alluvium deposits that are recorded in the north of the Site.
Superficial	Crag Formation	2.0	8.0	6.0	Unit is present to the north of the development but not present on BGS maps
Superficial	River Terrace Deposits (Encountered in one location (BGS borehole TG11SW129))	Ground level	24.1	24.1	The unit is present to the north of the Alluvium deposits that are recorded in the north of the Site.

Aquifer	Strata	Top of stratum (m)	Bottom of stratum (m)	Thickness (m)	Distribution across the site
Superficial	Sheringham Cliffs Formation (Referred to as Glacial Sand and Gravel in BGS borehole logs)	0.3 – 30.5	9.15 – 40.25	5.20 – 27.40	Dominates the superficial deposits for the majority of the Site.
Superficial	Lowestoft Formation (Referred to as Lowestoft till members (as part of the Lowestoft Formation) in Boulder Clay in BGS borehole logs)	0.9 - 24.1	5.5 – 30.5	2.44 – 10.00	The unit is present in the south of the Site in the vicinity of the A47.
Superficial	Happisburgh Glacigenic Formation	Not encountered	Not encountered	Not encountered	Potentially present in localised areas across the Site.

Aquifer	Strata	Top of stratum (m)	Bottom of stratum (m)	Thickness (m)	Distribution across the site
Bedrock	White Chalk Subgroup	8 – 40.25	10 – 65.55	0.9 – 25.3 (base not proven)	Underlies the entire Site.

2.5 Hydrology and Hydrogeology

2.5.1 The aquifer classification as designated by the Environment Agency (EA) for each geological unit is as follows:

- Alluvium – Secondary B Aquifer
- Head Deposits – Secondary B Aquifer
- Crag Formation – Secondary
- River Terrace Deposits – Secondary A Aquifer
- Sheringham Cliffs Formation – Secondary A Aquifer
- Lowestoft Formation – Secondary Undifferentiated Aquifer
- Happisburgh Glacigenic Formation – Secondary Undifferentiated Aquifer
- White Chalk Subgroup (undifferentiated) – Principal Aquifer.

2.5.2 There is the potential for Topsoil and Made Ground deposits to be present, however there is no EA aquifer classification for this stratum.

2.5.3 There are fifteen surface water abstractions noted within 250m of the Option C alignment. The nearest surface water abstraction is noted 24m to the southwest registered by Ebony Holdings Limited for spray irrigation for five separate occasions between 1994 to 2010. The remaining abstractions were also related to spray irrigation from surface water abstraction.

2.5.4 There are two groundwater abstractions noted within 250m of the Option C alignment. The nearest groundwater abstraction is noted 108m to the east within Low farm registered by S Thorogood and Sons for well and borehole abstraction from the Chalk Aquifer for agricultural uses.

2.5.5 There were several on site water features relating to field drains to the south and centre and tributaries of River Wensum and the River Wensum in the north.

2.5.6 There is the potential for groundwater to be present in Made Ground deposits, however it is considered unlikely to be a continuous groundwater body, but rather localised pockets of perched water that are likely to be recharged by surface water infiltration.

2.6 Preliminary Hydrological Model

2.6.1 Made Ground may be present in isolated pockets across the Site due to historical development, however the thickness and composition are likely to be highly variable. Groundwater may be present as perched water within the Made Ground, associated with lenses of permeable material which are recharged by surface water infiltration.

2.6.2 The underlying chalk bedrock has been classified as a Principal Aquifer. Groundwater is anticipated to present within the Chalk, at approximately 14.60 m to 15.50 m below ground level (bgl), based on information recorded on historical borehole logs. Within historic borehole logs, groundwater was not encountered within the superficial deposits, however, should groundwater be present within superficial deposits, it is likely that it will be in hydraulic continuity with groundwater within the Chalk aquifer.

2.7 Regulatory Database

2.7.1 The Envirocheck report includes information and data collected from several organisations including the Environment Agency (EA), the Local Authority, the British Geological Survey (BGS), Department for Environment, Food & Rural Affairs (Defra) and Health & Safety Executives (HSE).

2.7.2 It is considered that the information listed in **Table 2-5** represents those of potential concern in relation of contamination at the Site.

Table 2-5 Summary of database searches (all distances are approximate)

Description	On-site	0-250 m	251-500 m	Details
Discharge Consents	0	1	1	Closest located 51m north-east of Site, at BDR Grain Store on Stoney Land, entailing a discharge onto land, which was issued in January 1989 and revoked October 1996.
Integrated Pollution Prevention and Control	0	0	1	One record relating to Biffa Waste Services Ltd located 477m north-east of the Site. The status is 'superseded by variation'.

Description	On-site	0-250 m	251-500 m	Details
Pollution Incidents to Controlled Waters	1	5	0	One record located on the northern part of the Site relating to the release of an unknown pollutant to a freshwater stream / river in December 1993. There are five off-site records which include the release of pollutants including oil and organic wastes: cattle manure (solid).
Licensed Waste Management Facilities (Landfill Boundaries)	0	0	2	Two records 233m north-east and 301m east (of the northern part of the Site), both relating to the Attlebridge Landfill
Licensed Waste Management Facilities (Locations)	0	0	2	Two records 301m east and 398m north-east (of the northern part of the Site) both relating to land / premises at Reepham Road.

Description	On-site	0-250 m	251-500 m	Details
Potentially Infilled Land (non-water)	1	4	4	One record located on the northern part of the Site recorded as unknown filled ground (pit, quarry etc).
Historical Landfill Sites	0	0	1	Located 300m east of the Site and received deposited waste including inert waste between December 1980 and December 1985.
Registered Landfill Sites	0	0	2	Two records within 500m of the Site. One is located 331m east which accepted construction and demolition waste, the record is noted to be superseded. The other record is located 349m east and accepted wastes including concrete waste and hardcore and rubble. The record is noted to be lapsed or cancelled.

Local Authority

2.7.3 Broadland District Council was contacted via email on 6th November 2019 regarding environmentally pertinent information relating to the Site. A response was received from the Environmental Management Officer on the 13th May 2020. A summary of the environmentally pertinent information is presented below:

- The council identified six areas of possible filled ground concentrated around the A47 in the south of Site. One of which is located within the Site boundary and the others are in close vicinity to the Site.
- The council informed of no knowledge of any past industrial / commercial uses on or close to the Site other than agriculture.
- The council has not declared any Sites as contaminated within the Site boundary as defined under the regulations.
- The council informed of the Attlebridge Landfill Site within 500m of the Site as previously discussed.

Environment Agency

2.7.4 The Environment Agency was contacted via email on 6th November 2019 regarding environmentally pertinent information relating to the Site. A summary of the environmentally pertinent information is presented below:

- The EA suggested that the proposed route does not cross any EPR / WML / historic landfill sites, however noted that the Attlebridge landfill was close to the Site. They noted that the Site had ceased accepting waste.
- The EA were unaware of any remedial works carried out at the Site or within 500m.

Planning History

2.7.5 The Norfolk County Council (County Planning Authority) and Broadland District Council Online Planning Portals were accessed on 6th November 2019, no environmentally pertinent information was determined.

Unexploded Ordnance (UXO)

2.7.6 A preliminary assessment of the Unexploded Ordinance (UXO) risk for the development has been undertaken (document reference NCCT41793-04-B-02-02) presented in the Desk Study for the Site. The findings of the report show that due to the proximity to a former airfield (RAF Attlebridge) to the north-west of Site, the development will require a detailed UXO threat and risk assessment. The old airfield has been assessed as being likely to contain WWI and WWII ordnance and would warrant further action to be undertaken.

2.7.7 No other areas of potential UXO hazards are identified within the proposed development.

3 Preliminary Conceptual Site Model

3.1 Introduction

3.1.1 The Conceptual Site Model (CSM) is based upon the environmental conditions of the site as described in the previous sections.

3.1.2 The methods used within this assessment followed a risk-based approach; with the potential environmental risk assessed qualitatively using the 'source-pathway-receptor' contaminant linkage concept introduced in the guidance documents (principally the EA's CLR11) on the practical implementation of the Environmental Protection Act 1990.

3.1.3 Environmental risk can be defined as the combination of the consequence of a harmful effect and the probability of its occurrence. The existence of a contaminant linkage is primarily dependant on site usage and environmental conditions.

- The environmental risk assessment has been carried out by identifying and evaluating the significance of the following:
- Potential Sources of Contamination: these include any actual or potentially contaminating materials and activities, located either on or in the vicinity of the site;
- Potential Pathways for Contamination Migration: these are the routes or mechanisms by which contaminants may migrate from the source to the receptor; and
- Potential Receptors of Contamination: these include future land users including residents, construction and maintenance workers and vegetation in the proposed areas of soft landscaping.

3.2 Potential Contamination Sources

3.2.1 **Table 3-1** provides a summary of the potential sources of contamination and the likely nature of such sources both on-site and in the immediate surroundings as highlighted in the Interpretive Desk Study Report.

Table 3-1 Potential sources of contamination

Potential sources of contamination	Potential contaminants of concern	Likely / anticipated distribution
On-site Contaminants within potential Made Ground soils	Full range of contaminants including metals, inorganics, mineral oils, PAHs TPHs, BTEX, ground gases (methane and carbon dioxide), and asbestos	In north of Site and where tracks / roads transect the Site.
On-site Potentially infilled land (Marl pit)	Ground gas (carbon dioxide and methane), PAHs, heavy metals, petroleum, hydrocarbons and asbestos.	In north of Site

Potential sources of contamination	Potential contaminants of concern	Likely / anticipated distribution
On-site Agricultural practices,	Fertilisers and pesticides.	Site wide.
On-site Historical nursery	Fertilisers and pesticides.	Northern section
Off-site Potential Made Ground	Range of contaminants including metals, inorganics (e.g. cyanide), petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), ground gas (methane and carbon dioxide) and asbestos.	Predominantly in the northern areas of Site.
Off-site Agricultural practices	Fertilisers and pesticides.	All directions, multiple directions site wide.
Off-site Historically in-filled Clay and Marl Pits and Attlebridge Landfill	Ground gas (carbon dioxide and methane), PAHs, heavy metals, petroleum, hydrocarbons and asbestos.	Multiple locations to the north of the Site.

3.3 Potential Receptors

3.3.1 In the context of the proposed development of the Site, the following potential receptors were identified:

Human Health

- Future Site users and workers – likely to be limited to the areas where the public can access (e.g. pedestrian footpaths);
- Construction workers and future maintenance workers; and
- Third party neighbours.

Controlled Waters

- Alluvium (Secondary B Aquifer);
- Head Deposits (Secondary B Aquifer);
- River Terrace Deposits (Secondary A Aquifer);
- Sheringham Cliffs Formation (Secondary A Aquifer);
- Lowestoft Formation (Secondary Undifferentiated Aquifer);
- Happisburgh Glacigenic Formation (Secondary Undifferentiated Aquifer);
- White Chalk Subgroup (Principal Aquifer); and
- The River Wensum, its associated flood plains located in the north of Site and multiple unnamed water features across the Site.

Future Infrastructure and Services

- Future below ground services; and
- Future below ground structures.

Flora and Fauna

- Future Flora.

3.4 Preliminary Conceptual Site Model (CSM)

3.4.1 **Table 3-2** provides an evaluation of the potential contaminant linkages that are considered to be plausible on the basis of the information currently available for the Site and the current / proposed end use.

Table 3-2 Plausible contaminant linkages

Potential contaminant sources	Receptor	Pathways	Comments
On-site • Potential Made Ground; • Potentially infilled land; • Agricultural Practices; • Plantations; and • Historical Nursery.	**Human Health** • Future Site users and workers; • Construction workers and future maintenance workers; and • Third party neighbours.	• Dermal contact; • Ingestion of impacted soil particles on Site, and windblown to adjacent land-uses; • Inhalation of dust and asbestos fibres, and windblown to adjacent land-uses; and • Migration of ground gas and volatile vapours into buildings or below ground structures.	Due to the nature of the proposed development, the risk of exposure to future site users and workers / maintenance workers is considered likely to be within localised areas of the Site i.e. areas of landscaping, therefore, the risk to future Site users is considered to be **Low**. Construction workers and future maintenance workers may come in contact with asbestos or contaminated soils / groundwater during ground works (e.g. dermal exposure or inhalation of particles, vapours or ground gases), therefore the risk to construction and future maintenance workers is considered to be **Low-Moderate**. However, these risks should be managed with the adherence to Health and Safety protocols during the works. There is a chance that windblown impacted soil, dust and asbestos fibres could migrate off-Site causing a risk to third party neighbours. However, given that a large proportion of the Site is surrounded by agricultural land, the risk to these areas is considered to be **Low**. It is considered likely that Made Ground deposits may be present in localised parts of the Site. However, given the nature of the proposed development the risk from ground gas is considered to be **Low**. Should buildings be part of the proposed road scheme, the risk should be reconsidered following a ground investigation including a ground gas risk assessment.

Potential contaminant sources	Receptor	Pathways	Comments
On-site • Potential Made Ground; • Potentially infilled land; • Agricultural Practices; • Plantations; and • Historical Nursery.	**Controlled Waters** • River Wensum and unnamed inland river / drains; • Secondary A, B and Undifferentiated Aquifers within the Superficial Deposits; and • Principal Aquifer within the Chalk Bedrock.	• Vertical and lateral leaching from impacted soil; and • Lateral migration within groundwater.	The River Wensum and associated flood plain crosses the Site in the north. In addition, there are multiple other unnamed water features located on Site. There is a potential for contaminated run off from the Site to enter these water courses. It is considered likely that the proposed development will have a surface water drainage system included within the design, therefore reducing the risk from contaminated run off to surface water courses. Based on the available information in the context of the proposed development, the risk to surface water receptors is considered to be **Low-Moderate**. The migration of contaminants vertically from shallow soils into the superficial Secondary A Aquifers, Secondary Undifferentiated Aquifers and bedrock Principal Aquifer has the potential to occur. However, the site is proposed to be a road scheme development with limited areas of soft landscaping. The risk to groundwater is considered to be **Low**
On-site • Potential Made Ground; • Potentially infilled land; • Agricultural Practices; • Plantations; and • Historical Nursery	**Future Flora**	• Plant Uptake	Due to reprofiling and embankments employed across the scheme, there are due to be some limited areas of soft landscaping. As such, the risk is considered to be **Low to Moderate**.
On-site • Potential Made Ground; • Potentially infilled land; • Agricultural Practices; • Plantations; and • Historical Nursery.	**Future Infrastructure and Services** • Future below ground services; and • Future below ground structures.	• Direct contact • Permeation of hydrocarbons though plastic pipes.	There is the potential for chemical attack on below ground concrete and the permeation of contaminants through plastic pipes. Given the nature of the proposed road scheme, the risk to future infrastructure and services is considered to be **Low**.

Potential contaminant sources	Receptor	Pathways	Comments
Off-site • Potential Made Ground; • Agricultural Practices; and • Historically in-filled Clay and Marl Pits and Attlebridge Landfill.	**Human Health** • Future Site users and workers; and • Construction workers and future maintenance workers.	• Inhalation of windblown dust and asbestos fibres. • Migration of ground gas.	There is the potential for dust and asbestos fibres to be blown from surrounding areas on to the Site. However, given the limited historical development of the area surrounding the Site and the nature of the proposed road scheme, the risk from windblown dust and fibres is considered to be **Low**. Ground gas generated by Made Ground in the north and infilled marl / clay pits surrounding the Site may migrate laterally within the subsurface and accumulate in enclosed; therefore, posing a risk of explosion or asphyxiation. However, within the proposed development, it is not considered likely that there will be many areas where ground gas could accumulate. Furthermore, the surrounding area is predominantly undeveloped agricultural land and therefore is unlikely to have significant ground gas generation potential. The area in the north, surrounding the A1067 is likely to have Made Ground deposits present. Based on the nature of the proposed improvement works the risk from ground gas to the Site from off-Site sources is considered to be **Low.**
Off-site • Potential Made Ground; • Agricultural Practices; and • Historically in-filled Clay and Marl Pits and Attlebridge Landfill	**Future Flora**	• Plant Uptake	Due to reprofiling and embankments employed across the scheme, there are due to be some limited areas of soft landscaping. As such, the risk is considered to be **Low to Moderate**.
Off-site • Potential Made Ground; • Agricultural Practices; and • Historically in-filled Clay and Marl Pits and Attlebridge Landfill	**Controlled Waters** • River Wensum and unnamed inland river / drains; • Secondary A, B and Undifferentiated Aquifers within the Superficial Deposits; and • Principal Aquifer within the Chalk Bedrock.	• Lateral migration of contaminants within groundwater.	Prior to site development, the migration of contaminants from off-site shallow soils into the superficial and bedrock aquifers has the potential to occur given the lack of hardstanding on the Site. However, the proposed road scheme will mostly incorporate hardstanding which means that there will be a lack of infiltration of surface water which would reduce the leaching of shallow contaminants potentially impacting the nearby River Wensum. The risk is considered to be **Low.**

Potential contaminant sources	**Receptor**	**Pathways**	**Comments**
Off-site • Potential Made Ground; • Agricultural Practices; and • Historically in-filled Clay and Marl Pits and Attlebridge Landfill	Future Infrastructure and Services • Future below ground services; and • Future below ground structures.	• Lateral migration of contaminants via impacted groundwater.	Given the limited historical development of the area surrounding the Site and the nature of the proposed road scheme, the depth of the groundwater, the risk to future infrastructure and services is considered to be **Low.**

4 Site Investigation Summary

4.1 Site Investigation Rationale

4.1.1 The intrusive site investigation was undertaken in two phases by James and Milton Drilling Limited between 20th August 2019 to 8th November 2019 and from 17th August 2020 and 22nd September 2020.

4.1.2 The factual information for the two phases of ground investigation works is reported within the following two reports:

- WSP: 70061370; Norwich Western Link; Factual Report; October 2020
- WSP: 70061370-WSP-RP-GEO-0002 - Norwich Western Link; Ground Investigation Report; October 2020
- The ground investigation scope included obtaining information for contaminated land and geotechnical design.

4.1.3 The geotechnical findings of the ground investigation works are reported within the WSP Ground Investigation Report for the site highlighted above.

4.1.4 A summary of the intrusive works relevant to this assessment is presented in **Table 4-1** below.

Table 4-1 Summary of intrusive works

Element of investigation	Details	Rationale
Cable Percussive Boreholes	Thirteen boreholes drilled to target depths of between 20.0m to 34.0m bgl	To provide information on shallow ground and groundwater conditions for contamination and geotechnical analysis. To investigation the geotechnical design parameters of the prevailing ground conditions

Element of investigation	Details	Rationale
Rotary Boreholes	Eight Rotary boreholes	To investigation the geotechnical design parameters of the prevailing ground conditions
Window Sampling Boreholes	Fifteen boreholes up to 5.0m bgl	To provide information on shallow ground and groundwater conditions for contamination and geotechnical analysis
Trial Pits	Six trial pits	BRE soakage tests carried out at each location.

4.1.5 During the investigation, 27 boreholes were installed with wells for monitoring of ground gas and groundwater monitoring and sampling. Some of the exploratory hole locations were installed with dual monitoring wells targeting different depths.

4.1.6 A summary of monitoring wells installed is presented in **Table 4-2**.

Table 4-2 Summary of monitoring wells

Exploratory hole	Shallow / deep installation (S/D)	Top and base of response zone (m bgl)	Top and base of response zone (m AOD)	Strata targeted
BH001	D	5.0 to 12.0	43.0 to 36.0	Sheringham Cliffs Formation
BH003	S	1.20 to 4.80	45.72 to 42.12	Sheringham Cliffs Formation

Exploratory hole	Shallow / deep installation (S/D)	Top and base of response zone (m bgl)	Top and base of response zone (m AOD)	Strata targeted
BH005	S	12.5 to 17.5	41.7 to 36.7	Sheringham Cliffs Formation
BH005	D	23.5 to 29.5	30.7 to 24.7	Sheringham Cliffs Formation
BH007	D	21.0 to 29.5	23.6 to 15.1	White Chalk Subgroup
BH010	S	12.0 to 15.5	12.64 to 9.14	White Chalk Subgroup
BH012	S	1.0 to 5.0	12.38 to 7.38	Sheringham Cliffs Formation/White Chalk Subgroup
BH013	S	1.0 to 2.75	8.67 to 6.92	Sheringham Cliffs Formation/White Chalk Subgroup
BH013	D	15.0 to 20.0	-5.33 to -10.33	White Chalk Subgroup
BH014	S	0.50 to 2.0	8.34 to 6.84	Alluvium
BH014	D	10.0 to 15.0	-1.16 to -6.16	White Chalk Subgroup

Exploratory hole	Shallow / deep installation (S/D)	Top and base of response zone (m bgl)	Top and base of response zone (m AOD)	Strata targeted
BH015	S	2.0 to 5.0	7.24 to 4.24	Alluvium
BH015	D	15.0 to 20.0	-5.76 to -10.76	White Chalk Subgroup
BH016	S	4.0 to 7.0m	5.59 to 2.59	Alluvium
BH016	D	17.0 to 20.0	-7.41 to -10.41	White Chalk Subgroup
BH019	S	2.0 to 8.50	7.92 to 1.42	Sheringham Cliffs Formation
BH019	D	15.0 to 20.0	-5.08 to -10.08	White Chalk Subgroup
BH020	S	2.0 to 5.0	11.01 to 8.01	Sheringham Cliffs Formation
BH020	D	9.0 to 14.0	4.01 to -0.99	White Chalk Subgroup
BH021	S	3.0 to 6.0	16.67 to 13.67	River Terrace Deposits
BH021	D	10.0 to 15.0	9.67 to 4.67	White Chalk Subgroup
BH030	S	5.0 to 7.0	21 to 19	Sheringham Cliffs Formation

Exploratory hole	Shallow / deep installation (S/D)	Top and base of response zone (m bgl)	Top and base of response zone (m AOD)	Strata targeted
BH031	S	2.0 to 4.2	19.19 to 16.99	Sheringham Cliffs Formation
WS101	S	2.0 to 3.0	41.07 to 40.07	Sheringham Cliffs Formation
WS102	S	2.0 to 4.50	48.82 to 46.32	Sheringham Cliffs Formation
WS103	S	2.0 to 4.30	37.76 to 35.46	Sheringham Cliffs Formation
WS105	S	2.0 to 4.50	54.63 to 52.13	Sheringham Cliffs Formation
WS106	S	2.0 to 4.50	46.9 to 44.4	Sheringham Cliffs Formation
WS107	S	2.0 to 4.50	35.9 to 33.4	Sheringham Cliffs Formation
WS108	S	3.0 to 4.0	30.01 to 29.01	Sheringham Cliffs Formation
WS109	S	2.0 to 4.50	38.25 to 35.75	Sheringham Cliffs Formation
WS110	S	2.0 to 5.0	21.04 to 18.04	White Chalk Subgroup

Exploratory hole	Shallow / deep installation (S/D)	Top and base of response zone (m bgl)	Top and base of response zone (m AOD)	Strata targeted
WS112	S	2.0 to 4.50	19.78 to 17.28	White Chalk Subgroup (with lense of Lowestoft Till)
WS113	S	2.0 to 4.50	17.99 to 15.49	Sheringham Cliffs Formation / White Chalk Subgroup
WS114	S	2.0 to 4.0	47.29 to 45.29	Sheringham Cliffs Formation

4.2 Laboratory testing: soils and leachates

4.2.1 Selected soil samples were submitted for chemical analysis at Envirolab (all UKAS and MCERTS accredited laboratories) for the following analytes:

- Metals – arsenic, cadmium, chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Organic Compounds – TPHs (total petroleum hydrocarbons), BTEX (benzene, toluene, ethyl benzene and xylene), speciated PAHs (polyaromatic hydrocarbons), VOCs (volatile organic compounds) and SVOCs (Semi Volatile Organic Compounds); Polychlorinated Biphenyls (PCBs), monohydric phenols; and
- Other – Soil Organic Matter (SOM), pH, cyanide (free and total), water soluble boron, Waste Acceptance Criteria (WAC), leachate preparation

(CEN 10:1 extraction) and asbestos screening (and quantification if positively identified).

4.2.2 The full results of the chemical analysis are presented in **Appendix C**.

4.3 Groundwater level monitoring

4.3.1 Long term groundwater level monitoring was undertaken on twenty-seven occasions from September 2019 to May 2021. A summary of the monitoring visits is summarised in **Appendix D.**

4.4 Laboratory testing: groundwater sampling

4.4.1 Groundwater samples were obtained from fifteen locations across the scheme on six occasions; sent to ALS Laboratories and analysed for the following:

- Metals – arsenic, boron, beryllium, cadmium, chromium, chromium VI, copper, lead, mercury, nickel, selenium and zinc;
- Organic Compounds – TPH speciated PAHs, phenols, BTEX, PAHs, VOCs and SVOCs; and
- Other – pH, cyanide (free and total), water-soluble boron, water-soluble sulphate, alkalinity, redox potential and ammonium (NH4+).

4.5 Deviations from original scope of works

4.5.1 As described in the WSP Ground Investigation Report for the site, there were several site risks that arose during the site investigation:

- Soft Topsoil – A wide area of the site was within farmland / floodplain and were regularly filled for crop farming. Regular irrigation and natural flooding / surface water contributed to soft topsoil. During the ground investigation, this created issues with vehicular access to different ground investigation locations.
- Flooding – Site work was suspended from November 2019 to January 2020 due to flooding and access constraints across the site.

Additionally, the groundwater monitoring programme was suspended between February 2020 and June 2020.

- An installation was not undertaken at WS104 due to access restrictions.
- Groundwater sampling could not be consecutively undertaken until April 2021 due to the winter / spring flooding events which prevented access to a majority of the locations.

5 Ground Conditions

5.1 Encountered Ground Conditions

5.1.1 A summary of the encountered ground conditions is summarised in **Table 5-1** below: Detailed logs of the ground conditions are included within the factual reports for the ground investigation works.

Table 5-1 Encountered ground conditions

Stratum	Aquifer Designation	Elevation of upper surface (m AOD)	Typical thickness (m)	Typical description
Surfacing	No Aquifer Designation	8.84 – 57.0	0.20 to 1.20	Grass over loose brown / greyish brown and orange brown gravelly silty sand / sandy gravel with frequent rootlets, fine to medium sub-angular to sub-rounded gravel of flint
Made Ground	No Aquifer Designation	11.4 – 47.55	0.25 to 0.50	Very loose dark brown slightly sandy topsoil, off white silt sized comminuted chalk, concrete and black asphalt gravel. Stiff light brown very sandy, slightly gravelly silty clay. Gravel is fine to medium angular to sub angular of flint, chalk and granite subbase. Light brown clayey fine sand with concrete, asphalt and flint gravel in a light brown matrix of clayey, fine to coarse sand.
Alluvium	Superficial Deposits	8.39 to 9.42	5.60 to 15.20	Orange brown and grey brown sandy gravel with fine to coarse angular to sub angular flint and flint cobbles. Brown slightly silty very gravelly fine to coarse sand Orange brown mottled light grey and light brown gravelly fine to medium sand, gravel is angular to sub angular fine to coarse flint gravel.
Head Deposits	Superficial Deposits	5.35	1.2 to 4.65	Stiff light brown to grey gravelly clayey fine to medium sand. Gravel is fine to coarse of flint and chalk. Medium dense to dense orangey brown very silty fine to medium sand.

Stratum	Aquifer Designation	Elevation of upper surface (m AOD)	Typical thickness (m)	Typical description
River Terrace Deposits	Superficial Deposits	12.71 to 19.37	4.0 to 9.20	Very loose to med dense orange brown slightly clayey fine to medium sand. Orange brown to brown slightly cobbly fine to medium gravelly sand. Gravel is fine to coarse sub angular to sub rounded flint
Sheringham Cliffs Formation	Superficial Deposits	9.22 to 56.65	1.90 to 30.1	A wide variety of gravelly sands and sandy gravels typically comprising very loose to dense dark to light orange brown / greyish brown very gravelly sands with black speckling at depth. Gravel is fine to coarse angular to sub angular of flint and cobbles of flint and chalk
Lowestoft Formation	Superficial Deposits	11.4 to 48.9	1.70 to 7.20	Soft to firm beige to light brown sandy slightly gravelly clay Firm light grey clay. Light yellow to yellowish brown fine to medium gravelly cobbly sand. Gravel is fine to coarse sub angular to sub rounded flint.
White Chalk Subgroup	Bedrock	-5.91 to 26.49	2.5 to 37.5 (not proven)	Off white silt sized comminuted chalk with some to significant orange staining Loose orange sandy gravelly chalk with flint and occasional quartz Very weak low-density chalk recovered as gravelly silts

5.1.2 It should be noted that the Happisburgh Formation was not encountered during this ground investigation.

5.1.3 A high-level summary of the ground conditions encountered is included in the sections below. Indicative geological cross sections showing the findings of the ground investigation works are included within **Appendix A**.

Surfacing

5.1.4 The majority of the Site is used for farming and as such, resulted in substantial quantities of topsoil. The thickest topsoil was encountered in four locations (BH010, WS101, WS107 and WS108) and typically described as loose brown clayey silty, slightly gravelly fine to medium sand.

5.1.5 The Sheringham Cliffs Formation was encountered at the surface in one location (WS112) and there were occasions where material classified as Made Ground was encountered at the surface (WS113 and WS122).

Made Ground (MG)

5.1.6 Made Ground was encountered in three of the fifty-four locations (BH001, WS112 and WS122). The thickest area of Made Ground was encountered at BH001 up to 0.7m adjacent to the southern point of the proposed link road.

5.1.7 Made Ground at BH001 is cohesive and comprised stiff light brown very sandy, slightly gravelly silty clay. Gravel is fine to medium angular to sub angular of flint, chalk and granite subbase.

5.1.8 Made Ground at WS112 and WS122 was located at the north-eastern portion adjacent to the A1067 and comprised light brown clayey fine sand with concrete, asphalt and flint gravel in a light brown matrix of clayey, fine to coarse sand.

5.1.9 There may be other localised areas of Made Ground present adjacent to areas where roads / or any other development has historically taken place.

Alluvium (ALL)

5.1.10 Alluvium deposits were encountered in six locations to a maximum depth of 15.5m bgl (BH016) and comprise of granular (brown slightly silty very gravelly fine to coarse sand). Four of the exploratory hole locations and situated in close proximity to the River Wensum (BH014, BH015, BH016 and BH019). The other two locations (WS122 and TP404A) were located south-west of the viaduct crossing and in an area of soft landscaping off the A1067.

Head Deposits

5.1.11 Head Deposits were only encountered in two locations across the site (BH001 and WS114). It was described as stiff to very stiff light brown slightly gravelly clay. Gravel is fine to medium angular to sub angular chalk gravel. This deposit was additionally described as medium dense grey gravelly fine to mediums sand. A maximum thickness of 4.9m was encountered in BH001.

River Terrace Deposits (RTD)

5.1.12 River Terrace Deposits were encountered in three locations (BH020, BH021 and WS103) with the thickest deposit encountered in BH021 (9.2m). This stratum was generally described as orange brown to brown slightly cobbly fine to medium gravelly sand. Gravel is fine to coarse sub angular to sub rounded flint.

Sheringham Cliffs Formation (SHFM)

5.1.13 The Sheringham Cliffs formation was encountered in forty-six locations and generally comprises of sand and gravel lithologies. The thickest deposit was encountered in BH005 (30.1m). The formation can be typically described as very loose to dense dark to light orange brown / greyish brown very gravelly sands and sandy gravels with black speckling at depth. Gravel is fine to coarse angular to sub angular of flint and cobbles of flint and chalk.

Lowestoft Formation

5.1.14 This formation is described as Lowestoft Till and was typically encountered in the deeper boreholes (eleven locations) either as bands / interbedded within the Sheringham Cliffs Formation or immediately overlying the White Chalk

Subgroup. The thickest deposit was encountered at BH002 with a thickness of 7.2m.

5.1.15 Lowestoft Till was logged as till with chalk gravels, whereas the general silt / clay layers within the granular glaciofluvial deposits were logged as till with flint gravels. Due to the similarities and overlap between these cohesive soils they have been classified as undifferentiated cohesive deposits.

White Chalk Subgroup

5.1.16 Chalk was encountered at twenty-three locations in the deeper boreholes as well as some trial pits. The chalk was recovered across the site at the base of the investigated strata, either as low density or as a structureless Grade Dm Chalk.

5.1.17 Following this classification, chalk was described as extremely soft at the top of the stratum, becoming blocky unweathered chalk from 13 to 20m bgl and down to the end of the borehole.

5.1.18 Chalk was generally off-white, composed of cream, locally slightly cobbly sandy SILT with some gravels. There were however some locations e.g. BH013, where the chalk was described as sandy silty subangular to rounded gravel. Gravel was described as very weak to weak medium density, white with occasional black and dark brown specks locally iron stained yellow brown and orange and subangular to subrounded fine to coarse chalk.

5.2 Observations of Visual / Olfactory Contamination

5.2.1 No observations of visual / olfactory contamination were noted during the investigation.

5.2.2 However, it should be noted that during an WSP ecology walkover in September 2019, a suspected sheet of corrugated asbestos roof panel was identified in an area of woodland to the south-east of BH110 and north of Ringland Lane. The panel was found intact and approximately 350m to the south-east of the proposed development.

6 Hydrogeological conditions

6.1 Groundwater strikes

6.1.1 Groundwater strikes were recorded during the ground investigation as summarised in **Table 6-1**. Full details of groundwater strikes are also shown on the exploratory hole logs included within the factual reports for the ground investigation works undertaken across the Site.

Table 6-1 Groundwater strikes encountered during investigation

Stratum	Depth (m bgl)	Strata of strike
BH003	1.5 (rose to 1.2)	Sheringham Cliffs Formation
BH008	18.0 (rose to 13.3)	Sheringham Cliffs Formation
BH010	14.5 (rose to 11.9)	Chalk
BH012	2.0	Sheringham Cliffs Formation
BH014	3.9 (rose to 2.4)	Alluvium
BH015	0.8	Alluvium
BH016	4.2	Alluvium
BH019	1.6	Sheringham Cliffs Formation
BH021	9.1 (rose to 8.7)	River Terrace Deposits
BH031	15.1 (rose to 15.0)	Chalk

6.1.2 In summary, groundwater strikes were recorded at depths between 1.5 and 18.0m. The addition of water within the cable percussive boreholes while drilling in the Sheringham Cliffs Formation across the 2019-2021 investigation made distinguishing water strikes difficult. The shallow groundwater strikes within the Alluvium (BH014, BH015 and BH016) and the Sheringham Cliffs Formation (BH012 and BH019) are likely attributed to being in close proximity to the floodplain of the River Wensum and its tributaries in the eastern part of the proposed development. Based on the similar geologies and strikes encountered within the floodplain, it is considered likely that the Alluvium and Sheringham Cliffs Formation may be in hydraulic continuity.

6.1.3 Further groundwater strikes within BH010 and BH031 were identified in the Chalk stratum which is indicative of a separate groundwater body within the deeper aquifer.

6.2 Monitored Groundwater Elevations

6.2.1 Groundwater level monitoring of boreholes was completed at up to twenty-seven exploratory hole locations within thirty-seven separate pipe installations from September 2019 to August 2021. Based on the nature of the site, there were occasions where either sections of the site and subsequently boreholes were flooded (namely February to July 2020) or boreholes were unable to be accessed.

6.2.2 A summary of recorded groundwater elevations encountered during post site investigation monitoring are presented in **Table 6-2**. All groundwater dip data is presented in **Appendix D**.

Table 6-2 Monitored groundwater elevations

Borehole	Number of monitoring visits	Response zone geology and depth (m bgl)	Water level (m bgl) Min	Water level (m bgl) Max	Water level (m aod) Min	Water level (m aod) Max
BH014d	19	Chalk - 10.0 - 15.0	Above Ground Level	0.31	~8.84	8.53
BH015s	19	All - 2.0 to 5.0	0.11	0.88	9.13	8.36
BH015d	19	Chalk - 15.0 to 20.0	0.10	0.90	9.14	8.34
BH016s	19	All - 4.0 to 7.0m	0.32	110	9.27	8.49
BH016d	19	Chalk - 17.0 to 20.0	0.32	1.30	9.27	8.29
BH019s	19	SHFM - 2.0 to 8.50	Ground Level	1.01	9.92	8.91
BH019d	19	Chalk - 15.0 to 20.0	Ground Level	1.01	9.92	8.92
BH020s	19	SHFM - 2.0 to 5.0	2.79	3.80	10.22	9.21
BH020d	19	Chalk - 9.0 to 14.0	2.81	3.70	10.20	9.31
BH021s	19	RTD – 3.0 to 6.0	Dry	1.26	Dry	18.41
BH021d	19	Chalk – 10.0 to 15.0	1.32	10.41	18.35	9.26
BH030	19	SHFM - 5.0 to 7.0	Dry	Dry	Dry	Dry
BH031	19	SHFM - 2.0 to 4.2	Dry	Dry	Dry	Dry
WS101	32	SHFM - 2.0 to 3.0	Dry	Dry	Dry	Dry
WS102	32	SHFM - 2.0 to 4.50	Dry	3.50	Dry	47.32
WS103	32	SHFM - 2.0 to 4.30	2.16	3.31	37.6	36.45
WS105	30	SHFM - 2.0 to 4.50	Dry	Dry	Dry	Dry
WS106	30	SHFM - 2.0 to 4.50	Dry	Dry	Dry	Dry

Borehole	Number of monitoring visits	Response zone geology and depth (m bgl)	Water level (m bgl) Min	Water level (m bgl) Max	Water level (m aod) Min	Water level (m aod) Max
WS107	32	SHFM - 2.0 to 4.50	Dry	Dry	Dry	Dry
WS108	32	SHFM - 3.0 to 4.0	Dry	Dry	Dry	Dry
WS109	32	SHFM - 2.0 to 4.50	Dry	Dry	Dry	Dry
WS110	24	Chalk - 2.0 to 5.0	Dry	Dry	Dry	Dry
WS112	27	Chalk - 2.0 to 4.50	Dry	3.60	Dry	19.44
WS113	27	SHFM/Chalk - 2.0 to 4.50	Dry	Dry	Dry	Dry
WS114	32	SHFM - 2.0 to 4.0	Dry	Dry	Dry	Dry

6.2.3 Of the thirty-seven groundwater installations, groundwater was recorded in twenty-three which were installed within the Alluvium, Sheringham Cliffs Formation and Chalk.

6.2.4 The boreholes installed within the shallow Sheringham Cliffs Formation (within the window sampler boreholes, with the exception of WS103) did not encounter groundwater during the investigation or on any subsequent groundwater monitoring visits.

6.2.5 Groundwater monitoring results from the site investigation indicates that groundwater underlying the Site generally flows in a north-easterly direction towards the River Wensum and its tributaries.

6.3 Updated Hydrogeological Model

6.3.1 From the information presented in this section, groundwater is noted to have been encountered within the Alluvium, Sheringham Cliffs Formation and the underlying Chalk bedrock. The Alluvium and Sheringham Cliffs Formation are both Secondary A aquifers and both encounter water in the majority of locations with the exception of the window sampling locations in the far east. The Chalk is a Principal Aquifer and groundwater is encountered in all locations with the exception of the window sampling locations. Where groundwater is encountered in the Chalk bedrock, it is noted that it rises into the level of the superficial deposits. As such, it is considered that the groundwater in the superficial deposits are in continuity with the groundwater in the Chalk bedrock.

6.3.2 Groundwater was not encountered in the majority of the window sampling boreholes which were screened in the Sheringham Cliffs Formation and Chalk indicating that the construction of the A1067 has locally impacted the groundwater regime in this area.

7 Contamination Assessment

7.1 Human Health Risk Assessment

Rationale

7.1.1 In the United Kingdom, the presence of contamination on a Site is generally only of concern if an actual or potentially unacceptable risk exists. Legislation and guidance on the assessment of contaminated sites, consistent with the European Union best practice, acknowledges the need for a tiered risk-based approach. This report represents a Generic Quantitative Risk Assessment (GQRA), being a comparison of site contaminant levels against highly conservative standards and compliance criteria including an assessment of the risk using the source-pathway-receptor model.

7.1.2 WSP has derived a set of Generic Assessment Criteria (GAC) for the CLEA generic land use scenarios using the CLEA Workbook v1.071 Excel modelling tool.

7.1.3 The CLEA workbook does not currently have capacity to derive criteria to assess risks from the inhalation of vapours derived from contaminants dissolved in groundwater. Therefore, a set of groundwater GACs has also been derived using the Johnson & Ettinger (J&E) approach.

7.1.4 Target concentrations within indoor air are based upon the Health Criteria Values (HCV) for each substance. They are a function of receptor inhalation rates and occupancy periods, as defined by the conceptual exposure model.

7.1.5 Target soil vapour concentrations above the water table have been calculated by dividing the target concentration by the steady-state attenuation factor coefficient between soil and indoor air. The attenuation factor has been calculated in accordance with the Johnson & Ettinger model, presented within the Environment Agency Science Report SC050021/SR3 (2009). The air-water partition coefficient (K_{aw}) has been used to predict the partitioning behaviour of each chemical between soil pore water and air. Where the

calculated GAC exceeds the solubility limit for the chemical, no GAC has been proposed.

7.1.6 Further details on the assumptions and methodologies adopted by WSP are presented in **Appendix E**.

7.1.7 Where appropriate, exceedances of GACs are compared against published Category 4 Screening Levels (C4SLs). These are only applicable for six compounds, namely arsenic, benzene, benzo(a)pyrene, cadmium, chromium VI, and lead. C4SL, are a set of generic screening criteria, which are more pragmatic, but represent a level of acceptable risk in the context of Part IIA of the 1990 Environmental Protection Act i.e. soil concentrations below a C4SL limit are considered to be 'definitely not contaminated' and pose at most a 'low level of toxicological concern'.

7.1.8 In assessing the risks to human health receptors, consideration has to be given to the depth of contaminant impacts and likelihood of exposure. Various guidance documents provide differing advice on this, as summarised below.

7.1.9 Environment Agency Report SC050021/SGV Using Soil Guideline Values (2009):

- *"For the standard residential or allotment land use, the critical soil volume is the area of an individual garden, communal play area or working plot from the surface to a depth of between 0.5 m and 1.0 m. This is the ground over which children are most likely to come into contact with soil or from which vegetable and fruit produce will be harvested."*

7.1.10 Environment Agency Report SC050021/SR3 Updated Technical Background to the CLEA Model (2009):

- *"The generic CLEA model assumes that the source of outdoor air contamination is present as a continuous layer from the surface to a depth of 1.0 m. This is broadly consistent with the conceptual model for*

the other direct contact exposure pathways including soil ingestion and dermal contact."

7.1.11 Environment Agency Report SC050021/SR4 CLEA Software (Version 1.05) Handbook (2009):

- "The CLEA software assumes that the contaminant source is uniformly distributed from the soil surface to a depth of at least one metre in open ground."
- "The assumption in the development of SGVs is that soil contamination is uniformly distributed across the site from the surface to a depth of at least one metre. This is consistent with the conceptual model for the other direct contact exposure pathways including soil ingestion and *dermal contact."*

7.1.12 WSP has given due consideration to the above references and has concluded as follows with regards to influencing depths:

- The SC050021/SR2 & SR3 references to 1.0 m influencing depth are predominately concerned with estimation of the vapour generation rates for volatile contaminants (for calculating screening criteria within the CLEA software), as opposed to an endorsement that depths up to a full metre would be contributing to direct contact, ingestion, and dust inhalation pathways. In terms of our assessments, WSP considers that for volatile contaminants, all depths have to be considered to have the potential to affect receptors; however, if these contaminants are present deeper than 1.0m, then the risk assessment may require further refinement due to the CLEA assumptions.

7.1.13 The proposed land use will be a new dual carriageway that will pass through sections of cutting and embankment, as well as incorporating several road overpasses and underpasses, wildlife crossings and pedestrian footbridges.

7.1.14 A final cut and fill plan has not been generated for the Site, however due to areas of proposed road development, it is anticipated that earthworks and

materials management will be required as part of the proposed development. Therefore, a conservative approach has been adopted whereby soil from all depths has been assessed against ingestion, dermal contact and inhalation pathways. Given the proposed road scheme end use, WSP derived highway GACs were utilised for soils obtained from the Site.

7.1.15 Soil organic matter (SOM) content of the soil samples obtained from across the Site were variable, ranging from <0.1% to 2.4%, with an average of 0.63%. Therefore, a SOM value of 1% was utilised to generate conservative screening criteria.

7.1.16 To assess the risk to human health from vapours derived from groundwater, a commercial land use and a sand soil type were assumed to generate conservative GAC.

7.1.17 Once the proposed redevelopment plans are confirmed, any changes to the land-use would require a re-assessment of the data and the risks in line with the proposed masterplan for the site.

7.2 Generic Quantitative Risk Assessment – Human Health

7.2.1 A total of 42 soil samples were obtained and tested as a part of the historical ground investigation works.

Soil Contamination

7.2.2 Laboratory analytical certificates are presented in **Appendix C** and screening tables are presented in **Appendix F**. It should be noted that the screening tables presented in **Appendix F** only presents data that were encountered above their respective laboratory detection limits.

7.2.3 When compared against the highways screening for both surface and sub-surface soils, there are no exceedances of the GAC.

Asbestos in Soils

7.2.4 Thirty-three samples were submitted for asbestos identification. Asbestos fibres were not detected in any of the tested samples.

7.2.5 However, it should be noted that during an ecology walkover in September 2019, a suspected sheet of corrugated asbestos roof panel was identified in an area of woodland to the south-east of BH110 and north of Ringland Lane. The panel was found intact and approximately 350m to the south-east of the proposed development.

7.2.6 Based on the current nature of the site and the nature of the proposed development, the risks to future site users are considered to be low, however, there is considered to be no safe exposure limit for asbestos and given the nature of asbestos it may be present in other areas of the Site and would therefore pose a risk to human health.

Groundwater Vapour

7.2.7 One hundred and eighteen groundwater samples were obtained from newly installed monitoring wells during the ground investigation works across six sampling rounds.

7.2.8 The groundwater results have been compared against GAC to assess the risk from vapour derived from dissolved contaminants in groundwater. The GAC assumed a future commercial land use and a sand soil type.

7.2.9 When compared against the groundwater vapour commercial screening criteria, there are no exceedances of the GAC.

7.2.10 The screening tables are presented in **Appendix F**.

Human Health Risk Evaluation

7.2.11 Compared against highways screening criteria, there are no exceedances of the GAC.

7.2.12 Asbestos fibres were not detected in any of the tested samples. Given the heterogeneous nature of the Made Ground deposits and the former land uses identified at the Site, the presence of asbestos within Made Ground in other areas of the Site cannot be discounted. However, the proposed highways land use includes the site being covered by hardstanding, therefore removing the pathway to future site users and third-party neighbours.

7.2.13 Asbestos containing materials (ACM) were not observed during the intrusive investigation and ACMs were not identified in any of the soil samples submitted for analysis from exploratory holes. However, this does not discount the possibility that ACMs and / or free fibres are present within Made Ground in the remainder of the Site.

7.2.14 Outside the scope of this investigation, a suspected sheet of corrugated asbestos roof panel was identified in an area of woodland to the south-east of BH110 and north of Ringland Lane. The panel was found intact and approximately 350 m to the south-east of the proposed development.

7.2.15 It should be noted that if asbestos were to be identified during development, a low to moderate risk would be present if the material is re-used in soft landscaped areas (i.e. embankments). Material would need to be managed under a wider Materials Management Plan (MMP) to ensure the suitability for re-use. An appropriate level of chemical testing and risk assessment should be undertaken to assess the suitability for re-use on site.

7.2.16 During the construction phases of the development, the risks to construction workers from contaminants and asbestos are considered to be Moderate. The risks should be managed through the appropriate use of PPE and RPE. Good construction practices (i.e. dust suppression, wheel washing) should be utilised to manage the risks to third party neighbours during construction phases. Guidance presented in CIRIA 733 “Asbestos in soil and made ground: a guide to understanding and managing risks” should be consulted when managing risks arising from asbestos.

7.2.17 Based on the evaluation above, the risk to human health is considered to be **Low**.

7.3 Generic Quantitative Risk Assessment – Controlled Waters

7.3.1 Three rounds of groundwater sampling were undertaken from 20 boreholes across 15 borehole locations.

Rationale

7.3.2 The generic controlled waters risk assessment was conducted in accordance with the principles of the EA 'Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination' 2006 and the 'prevent and limit' approach of the Water Framework Directive (2000/60/EC). Generic Controlled Waters risk assessments compare directly measured concentrations with standard assessment criteria.

7.3.3 Water Quality Standards (WQS) are selected based on both a hierarchy of relevance to England and the receptor. In this case, Controlled Waters receptors identified in the CSM were;

- **Aquifers**: Alluvium and Head Deposits (Secondary B Aquifers); River Terrace Deposits, Sheringham Cliffs Formation (Secondary A Aquifer), Lowestoft Formation and Happisburgh Glacigenic Formation (Secondary Undifferentiated Aquifers); White Chalk Subgroup (Principal Aquifer); and
- **Surface Water**: The River Wensum, its associated flood plains located in the north of Site and multiple unnamed water features across the Site.

7.3.4 The following hierarchies of WQS were considered to be appropriate:

Aquifers

- UK Drinking Water Quality Standards (DWS) from The Water Supply (Water Quality) Regulations 2000 (amended 2004);
- World Health Organisation Guidelines for Drinking Water Quality, Fourth Edition, Volume 1, (2011); and
- World Health Organisation Petroleum Products in Drinking Water (2008).

Surface water

- Environmental Quality Standards (EQS) from The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

7.3.5 Hardness, pH and dissolved organic carbon within the River Wensum can affect the bioavailability of copper, manganese, nickel and zinc. Site specific EQSs may be derived using the WFD-UKTAG metal bioavailability tool (m-BAT) (Water Framework Directive – United Kingdom Technical Advisory Group (WFD-UKTAG) 'UKTAG River & Lake Assessment Method, Specific Pollutants (Metals): Metal Bioavailability Assessment Tool (M-BAT)' ISBN: 978-1-906934-57-6 (July 2014)). The River Wensum and its tributaries were not sampled so 100% bioavailability was assumed in order to maintain conservatism.

7.3.6 Further details on the assumptions and methodologies adopted by WSP are presented in **Appendix E**.

Soil Leachate

7.3.7 Seven samples of strata defined as Topsoil were submitted for leachate analysis to assess the potential risks to Controlled Water receptors from soils underlying the Site. **Table 7-1** presents a summary of the potential contaminants of concern that were encountered above the DWS and EQS screening criteria. The screening tables are presented in **Appendix F.**

Table 7-1 Summary of exceedances of EQS and DWS for soil leachate

Analyte	EQS µg/L	DWS µg/L	Number of EQS exceeds	Number of DWS exceeds	Maximum concentration (µg/l)	Location of maximum concentration
Anthracene	0.1	No GAC	3	0	0.12	BH002 at 0.5mbgl

Analyte	EQS µg/L	DWS µg/L	Number of EQS exceeds	Number of DWS exceeds	Maximum concentration (µg/l)	Location of maximum concentration
Fluoranthene	0.0063	No GAC	6	0	0.27	BH002 at 0.5mbgl
Ammoniacal Nitrogen as NH4	0.257	0.5	1	1	0.508	BH002 at 0.5mbgl
Copper	1.0	2000	7	0	9.0	WS107 at 0.5mbgl
Lead	1.2	10	6	2	12	BH003 at 0.2mbgl
Nickel	4	20	1	0	4	BH003 at 0.2mbgl
Zinc	12.3	No GAC	6	o	89	BH006 at 0.2mbgl
Aromatics > C8-C10	20	300	2	0	63	WS107 at 0.50mbgl
Aromatics > C10-C12	2	90	1	0	34	BH006 at 0.2mbgl
Aromatics >C12 -C16	2	90	2	0	36	BH006 at 0.2mbgl
Aromatics >C16 -C21	0.1	90	1	0	12	WS109 at 0.2mbgl

7.3.8 DWS and EQS exceedances relate to heavy metals, PAHs, TPH and inorganics. These are leachable from the selected soil samples, though marginally above the concentrations. It should be noted that the limit of detection for benzo (a) pyrene was greater than the EQS value. Manganese, nickel and copper of EQS was common across the site. Maximum concentrations were generally centred around the River Wensum and its tributaries. Based on the shallow water table (groundwater strikes <1.0m bgl) and exceedances, this suggests a potential plausible pollutant linkage and risk to surface water from soil leachate via infiltration. However, it should be noted that only limited Made ground deposits were identified on the Site therefore, the concentrations of contaminants noted may be indicative of background concentrations of the natural strata on the Site or agricultural practices.

Groundwater

7.3.9 One hundred and eighteen groundwater samples were obtained from newly installed monitoring wells during the WSP ground investigation works across six sampling rounds which were:

- First round - 14 April 2021
- Second round – 28 April 2021
- Third round – 12 May 2021
- Fourth round – 9 June 2021
- Fifth round – 23 June 2021
- Sixth round – 7 July 2021

7.3.10 Sampling was only undertaken at a time when access was possible to all locations.

7.3.11 Eighteen samples were taken from the Alluvium (BH014S, BH015S, BH016S), forty-two were taken from the Sheringham Cliffs Formation (all shallow installations of BH001 – BH013; BH019-BH020, WS103 and deep installation of BH005), five were taken from a borehole which screened the SHFM and Chalk strata (BH012) and fifty-three were taken from the Chalk strata (all deep installations of BH001 – BH013; BH019-BH020).

7.3.12 Laboratory analytical certificates are presented in **Appendix C** and screening tables are presented in **Appendix F**. It should be noted that the screening tables only presents data that were encountered above their respective laboratory detection limits.

7.3.13 **Table 7-2** presents a summary of the potential contaminants of concern that were encountered above the EQS and DWS screening criteria.

Table 7-2 Summary of groundwater exceedances for EQS and DWS

Analyte	EQS (µg/L)	Number of EQS exceedances	DWS (µg/L)	Number of DWS exceedances	Maximum concentration (µg/L)	Location of maximum concentration and geology
Iron	1000	8	200	18	3430	BH014 – Chalk
Lead	1.2	1	10	0	2	BH019 – Chalk
Manganese	123	59	50	74	1650	BH016 – Alluvium
Nickel	4	40	20	0	17	BH013 (shallow and deep)- Sheringham Cliffs and Chalk
Zinc	12.3	10	No GAC	-	29	BH005 – Sheringham Cliffs Formation
Fluoranthene	0.0063	0	No GAC	3	0.02	WS103 (SHFM) BH020 (Chalk)
Aromatics >C12-C16	2	28	90	0	81	BH014 – Alluvium
Aromatics >C16-C21	0.1	23	90	0	80	BH014 – Alluvium
Aromatics >C21-C35	0.00017	4	90	0	15	BH014 (deep and shallow) - Alluvium and Chalk

7.3.14 DWS and EQS exceedances relate to ammoniacal nitrogen, heavy metals, PAH and TPH. All locations screened groundwaters within the Alluvium, Sheringham Cliffs Formation and Chalk.

7.3.15 Copper, manganese and TPH of EQS was common across site and ammoniacal nitrogen was present across site. All other exceedances were generally sporadic.

7.3.16 The majority of the maximum exceedances of heavy metals, inorganics and PAH noted within the Chalk bedrock aquifer are potentially related to background concentrations of the natural strata underlying the Site, and / or wider regional background concentrations from agricultural practices in the surrounding area.

7.3.17 Exceedances of EQS in the Alluvium are noted within boreholes in close proximity to the River Wensum. These are thought to be related to surrounding widespread leaching of soils. Additionally, groundwater levels in these boreholes were shallow and, on some occasions, flooded completely to ground level which would suggest that surface water may have impacted groundwater in the underlying Alluvium.

7.3.18 Based on the groundwater levels noted during the monitoring rounds, shallow groundwater levels identified within the superficial deposits and bedrock suggest that the groundwater within these units are in continuity with each other.

Groundwater Assessment Summary

7.3.19 Based on the assessment of the soil leachate and groundwater results, the risk to groundwater in the Alluvium, Sheringham Cliffs Formation and Chalk underlying the Site are considered to be **Low**. Risk to the River Wensum and tributaries from groundwater within the superficial deposits underlying the Site is considered to be **Low**.

7.3.20 This assessment is based upon the following:

- There are no sources of potential contamination identified such as contaminated Made Ground.
- The leachate exceedances are marginal and are likely to be associated with background concentrations of contaminants within the natural strata underlying the Site.
- The Site is proposed to be covered in hardstanding at the road surface which would provide betterment and reduce infiltration of rainwater into the ground and therefore limit the mobilisation of potential contaminants of concern.
- Based on there being no historical development across the Site and limited Made ground deposits identified on the Site, the contaminants of concern are considered likely to be associated with background concentrations within the underlying natural strata and / or the regional groundwater quality of the local area.
- Exceedances of EQS in the Alluvium are noted within boreholes in close proximity to the River Wensum. These are thought to be related to surrounding widespread leaching of soils. Additionally, groundwater levels in these boreholes were shallow and, on some occasions, flooded completely to ground level which would suggest that surface water may have impacted groundwater in the underlying Alluvium.
- Regarding DWS exceedances, there are no groundwater abstractions utilised for the abstraction of drinking water located within the vicinity of the Site.

7.4 Ground Gas Risk Assessment

7.4.1 Ground gas monitoring of the installed borehole wells was monitored on up to twelve occasions between 24 September 2019 and 4 August 2021. There were sixteen out of thirty five gas monitoring wells installed (within the shallow

Alluvial deposits (BH014s, BH015s, BH016s), shallow Sheringham Cliffs Formation (BH003, BH005d, BH013s, BH019s) and deeper stratum targeting the Chalk (BH010, BH013d, BH014d, BH015d, BH016d, BH019d, BH020d, BH021d)) that were found to have their response zones flooded during monitoring events, therefore, gas monitoring data from these wells has been discounted from the assessment as it is not considered to be representative of the ground gas regime underlying the Site.

7.4.2 Atmospheric pressure was recorded at the beginning and end of each monitoring round and are presented in **Table 7-3.** Included within the table are atmospheric pressure trends according to the Wunderground website, which has pressure data from a nearby weather station.

Table 7-3 Atmospheric pressure during gas monitoring rounds

Round	Date	Atmospheric pressure (start)	Atmospheric pressure (end)	Atmospheric pressure trend	Wunderground atmospheric pressure trend (Data obtained from Taverham Weather Station)
Round 1	27/09/2019	1016	1016	Stable	Falling
Round 2	02/10/2019	1021	1023	Rising	Falling
Round 3	09/10/2019	994	996	Rising	Falling
Round 4	22/10/2019	1015	1013	Falling	Falling
Round 5	14/11/2019	991	991	Stable	Falling
Round 6	27/11/2019	973	974	Rising	Falling
Round 7	09/12/2019	998	1009	Rising	Falling
Round 8	13/01/2020	1003	1003	Stable	Falling
Round 9	30/01/2020	995	994	Falling	Falling
Round 10	19/02/2020	1006	1011	Rising	Falling
Round 11	17/06/2020	1003	1007	Rising	Falling
Round 12	01/07/2020	994	998	Rising	Rising
Round 13	15/07/2020	1006	1006	Stable	Rising
Round 14	29/07/2020	1006	1005	Rising	Falling
Round 15	15/10/2020	1017	1019	Rising	Falling
Round 16	28/10/2020	993	994	Rising	Rising
Round 17	11/11/2020	1011	1012	Rising	Falling

Round	Date	Atmospheric pressure (start)	Atmospheric pressure (end)	Atmospheric pressure trend	Wunderground atmospheric pressure trend (Data obtained from Taverham Weather Station)
Round 18	25/11/2020	1003	1004	Rising	Rising
Round 19	09/12/2020	1000	1000	Stable	Rising
Round 20	22/12/2020	1004	1004	Stable	Rising
Round 21	06/01/2021	1012	1012	Stable	Falling
Round 22	20/01/2021	980	979	Falling	Falling
Round 23	03/02/2021	987	985	Falling	Falling
Round 24	17/03/2021	1023	1022	Falling	Falling
Round 25	14/04/2021	1031	1032	Rising	Falling
Round 26	28/04/2021	999	999	Stable	Falling
Round 27	12/05/2021	1005	1005	Stable	Falling
Round 28	09/06/2021	1021	1021	Stable	Falling
Round 29	23/06/2021	1018	1018	Stable	Falling
Round 30	07/07/2021	1009	1010	Rising	Falling
Round 31	21/07/2021	1017	1017	Stable	Falling
Round 32	04/08/2021	1005	1005	Stable	Falling

7.4.3 Gas Screening Values (GSV) have been calculated based on the ground gas data collected in accordance with CIRIA C665 guidance. The GSV is calculated for each monitoring well as the maximum flow rate multiplied by the maximum methane or carbon dioxide concentration. Where flow rate and / or methane / carbon dioxide concentrations have been encountered below the limit of detection of the development, a value of 0.1l/hr and 0.1% v/v have been used to calculate GSV, respectively. A summary of the ground gas data and calculated GSV are presented in **Table 7-4**. Monitoring results are presented and appended in the recent WSP Ground Investigation Report and in **Appendix G**.

7.4.4 Notes for **Table 7-4:**

- Regarding the maximum flow rate, the recorded value was 0.0. The value has been changed to 0.1 to enable results to be derived.
- The abbreviation SHFM has been used to denote the Sheringham Cliffs Member and CHALK to denote the White Chalk Subgroup.

Table 7-4 Ground gas summary and GSV

Exploratory Hole	Response zone strata and depth (m bgl)	Maximum flow (l/hr)	Maximum CH_4 (% v/v)	Maximum CO_2 (% v/v)	Methane GSV	Carbon dioxide GSV
BH001	SHFM – 5.0 – 12.0	0.1	0.0	1.8	0.0	0.0018
BH005s	SHFM – 12.5 – 17.5	0.	0.0	1.7	0.0	0.0017
BH007	Chalk – 21.0 – 29.5	0.1	0.0	1.8	0.0	0.0018
BH012	SHFM/Chalk – 1.0 – 5.0	0.1	0.0	1.6	0.0	0.0016
BH020s	SHFM – 2.0 to 5.0	0.1	0.0	1.0	0.0	0.001
BH021s	RTD – 3.0 to 6.0	0.1	0.0	2.3	0.0	0.0023
BH030	SHFM – 5.0 to 7.0	0.1	0.0	1.3	0.0	0.0013
BH031	SHFM – 2.0 to 4.2	0.1	0.0	1.2	0.0	0.0012
WS101	SHFM – 2.0 to 3.0	0.1	0.0	4.3	0.0	0.0043
WS102	SHFM – 2.0 to 4.50	0.1	0.0	4.1	0.0	0.0041
WS103	SHFM – 2.0 to 4.30	0.1	0.0	1.6	0.0	0.0016
WS105	SHFM – 2.0 to 4.50	0.1	0.0	1.1	0.0	0.0011
WS106	SHFM – 2.0 to 4.50	0.1	0.0	1.6	0.0	0.0016
WS107	SHFM – 2.0 to 4.50	0.1	0.0	2.0	0.0	0.002
WS108	SHFM – 3.0 to 4.0	0.1	0.0	1.8	0.0	0.0018
WS109	SHFM – 2.0 to 4.50	0.1	0.0	2.2	0.0	0.0022
WS110	Chalk – 2.0 to 5.0	0.1	0.0	7.0	0.0	0.007
WS112	Chalk – 2.0 to 4.50	0.1	0.0	1.0	0.0	0.001
WS113	SHFM/Chalk – 2.0 to 4.50	0.1	0.0	1.6	0.0	0.0016
WS114	SHFM – 2.0 to 4.0	0.1	0.0	1.3	0.0	0.0013

7.4.5 With respect to data suitability, for a low sensitivity end use (commercial – road) and low source generation, CIRIA C665 recommends a minimum of six ground gas monitoring visits over a period of two months. CIRIA C655 also recommends that ground gas monitoring is undertaken during low (<1000 mb) and falling pressure conditions since this is considered to represent a worst-case scenario. As such, these minimum requirements have been met by the monitoring.

7.4.6 Deplete oxygen concentrations were not recorded during the twelve monitoring visits, with concentrations recorded to range from 12.7% (v/v) to 21.0% (v/v). No carbon monoxide, PID readings or hydrogen sulphide readings were taken during the monitoring rounds.

7.4.7 Based on the monitoring data, a maximum GSV of 0.00 l/hr was calculated for methane, and a maximum GSV of 0.007 l/hr was calculated for carbon dioxide. These maximum values do not exceed the 0.07 l/hr limit for Characteristic Situation 1 for methane or carbon dioxide. However, carbon dioxide concentrations at WS110 (installed in Chalk), exceeded 5 % v/v during monitoring rounds; therefore, CIRIA C665 guidance suggests an upgrade to Characteristic Situation 2 (**Low Risk**).

7.4.8 However. It should be noted that the proposed development is a proposed road scheme, the use of the CIRIA 665 assessment is not strictly appropriate. Risks to construction and maintenance workers from ground gas are recommended to be managed through health and safety protocols.

7.5 Preliminary Potable Water Supply Pipe Assessment

7.5.1 Available soil analytical data was compared to criteria from the UK Water Industry Research ‘Guidance for the Selection of Water Supply Pipes to be Used in Brownfield Sites’ document.

7.5.2 Based on the available data and the preliminary assessment, barrier pipes are considered to be required if pipes are to be installed within Made Ground deposits. However, it should be noted that this is a preliminary assessment,

and any pipe design should be subject to the appropriate testing in service trenches and agreed with the relevant statutory authority.

7.6 Phytotoxicity assessment

7.6.1 Guidance on the effects of metal contamination on plant growth is provided within the Ministry of Agriculture, Fisheries and Food (MAFF) Code of Good Agricultural Practice for the Protection of Soil. Soil samples were screened against phytotoxic screening criteria to assess risk to plant life which could be implemented as part of the soft landscaping design. Screening tables are presented in **Appendix F**.

7.6.2 A summary of the test results versus the recommended phytotoxic screening criteria is provided in **Table 7-5**.

Table 7-5 Summary of soil results screened against phytotoxicity criteria

Analyte	Screening value (mg/kg)	Concentration range (mg/kg)	Average concentration (mg/kg)	Average concentration above screening value
Copper	100	2 – 16	5	No
Nickel	300	3 – 565	24.47	No
Zinc	200	8 – 91	28.86	No

7.6.3 Based on the average of results from samples obtained during the initial investigation, no exceedances of the MAFF values were noted. As such, an overall phytotoxic risk to plants is considered to be **Low**.

8 Refined Conceptual Site Model

8.1 On-site

8.1.1 Following the findings of the GQRA, the preliminary Conceptual Site Model (CSM) has been revised. A revised list of contaminant linkages is presented in **Table 8-1** and is based upon an evaluation of the potential sources, future receptors and the environmental setting of the Site.

Table 8-1 Contaminant linkage

Contaminant linkage (CL)	Source	Pathway	Receptor	Comments
CL 1	Asbestos	Inhalation within areas of soft landscaping	Site users, workers and visitors Construction / maintenance workers Third party neighbours	Asbestos fibres were not detected in any of the tested samples. Given the heterogeneous nature of the Made Ground deposits and the former land uses identified at the Site, the presence of asbestos within Made Ground in other areas of the Site cannot be discounted. However, the proposed highways land use includes the site being covered by hardstanding, therefore removing the pathway to future site users and third-party neighbours. It should be noted that if asbestos were to be identified during development, a **low to moderate** risk would be present if the material is re-used in soft landscaped areas (i.e. embankments). Material would need to be managed under a wider Materials Management Plan (MMP) to ensure the suitability for re-use. An appropriate level of chemical testing and risk assessment should be undertaken to assess the suitability for re-use on site. Following mitigation, the risks in unsealed areas are considered to be **Low**.
CL 2	Dissolved contaminants in groundwater	Inhalation of vapours Direct contact	Site users, workers and visitors Construction / maintenance workers Third party neighbours	There is not considered to be a risk to human health from groundwater vapour. The risk to construction / maintenance workers from inhalation of vapours within the shallow groundwater is considered to be Low

Contaminant linkage (CL)	Source	Pathway	Receptor	Comments
CL 3	Dissolved heavy metals, PAHs, TPH and inorganics	Vertical and lateral migration within groundwater	Superficial deposits (Alluvium and Sheringham Cliffs Formation – Secondary A Aquifers) Bedrock deposits (Chalk – Principal Aquifer) River Wensum	Based on the assessment of the soil leachate and groundwater results, the risk to groundwater in the Alluvium, Sheringham Cliffs Formation and Chalk underlying the Site are considered to be Low. Risk to the River Wensum and tributaries from groundwater within the superficial deposits underlying the Site is considered to be Low. This assessment is based upon the following: • There are no sources of potential contamination identified such as contaminated Made Ground. • The leachate exceedances are marginal and are likely to be associated with background concentrations of contaminants within the natural strata underlying the Site. • The Site is proposed to be covered in hardstanding at the road surface which would provide betterment and reduce infiltration of rainwater into the ground and therefore limit the mobilisation of potential contaminants of concern. • Based on there being no historical development across the Site and limited Made ground deposits identified on the Site, the contaminants of concern are considered likely to be associated with background concentrations within the underlying natural strata and / or the regional groundwater quality of the local area. • Exceedances of EQS in the Alluvium are noted within boreholes in close proximity to the River Wensum. These are thought to be related to surrounding widespread leaching of soils. Additionally, groundwater levels in these boreholes were shallow and, on some occasions, flooded completely to ground level which would suggest that surface water may have impacted groundwater in the underlying Alluvium. Regarding DWS exceedances, there are no groundwater abstractions utilised for the abstraction of drinking water located within the vicinity of the Site.
CL 4	Contaminants in soils	Direct contact with impacted soils	Future below ground services (e.g. potable water supply pipes) Future building structures	Based on the available data and the preliminary assessment, barrier pipes are considered to be required if pipes are to be installed within Made Ground and superficial deposits. However, it should be noted that this is a preliminary assessment, and any pipe design should be subject to the appropriate testing in service trenches and agreed with the relevant statutory authority.

Contaminant linkage (CL)	Source	Pathway	Receptor	Comments
CL 5	Made Ground and Alluvial soils Potentially infilled land Agricultural Practices	Migration of ground gas and volatile vapours.	Construction / maintenance workers Third party neighbours	There have been no elevated concentrations of methane and carbon dioxide noted on the Site. Based on the initial findings, the Site is classified as Characteristic Situation 2, indicating ground gas protection measures may be required. However, it should be noted that the proposed development is a proposed road scheme, the use of the CIRIA 665 assessment is not strictly appropriate. Risks to construction and maintenance workers from ground gas are recommended to be managed through health and safety protocols.
CL6	Contaminants in soil	Plant uptake	Plant life in landscaped areas	No exceedances of the MAFF values were noted. As such, an overall phytotoxic risk to plants is considered to be **Low**.

8.2 Off-site

8.2.1 Based on the findings of the ground investigation and subsequent GQRA, a potential risk from off-site sources has been identified details of which have been summarised in **Table 8-2.**

Table 8-2 Assessment of off-site sources

Source	Pathway	Receptor	Comments
Historical and current agricultural land use surrounding the site	Vertical and lateral; migration within groundwater	**Controlled Waters** Superficial deposits (Alluvium and Sheringham Cliffs Formation – Secondary A Aquifers) Bedrock deposits (Chalk – Principal Aquifer) River Wensum	Exceedances of EQS and DWS within the Alluvium, Sheringham Cliffs Formation and the Chalk are likely related to wider regional background levels and from agricultural practices in the surrounding area from widespread leaching of soils. There has been evidence of heavy metals exceedance in soil leachate which suggests that these contaminants mobilised during flooding events which created a pathway to impact surface water and vertically down towards groundwater within the Chalk Aquifer. However, based on the nature of the proposed development and the groundwater levels recorded on the Site, the risk to Controlled Waters from off-site sources is considered to be Low-Moderate.
Historical and current agricultural land use surrounding the site	Dermal contact Ingestion of impacted soil particles on Site, and windblown to adjacent land-uses Inhalation of dust and asbestos fibres, and windblown to adjacent land-uses	**Human Health** Site users, workers and visitors Construction / maintenance workers Third party neighbours	The majority of the area surrounding the site is agricultural with the exception of the major A roads north and south and some roads bisecting the site. There is the potential for off-site sources such as dust and asbestos fibres to be blown from surrounding areas on to the Site. However, given the limited historical development of the area surrounding the Site and the nature of the proposed road scheme, the risk from windblown dust and fibres is considered to be Low. Ground gas monitoring has not identified the presence of significant ground gas and volatile vapours within the site. The ground gas and vapour risk from offsite sources is considered to be Low.
Historical and current agricultural land use surrounding the site	Lateral migration of contaminants via impacted groundwater	**Building Fabric and Services** Below ground services; and Building structures.	Ground gas and vapours generated from contaminated groundwater in the areas surrounding the site, may migrate laterally in the subsurface and accumulate in enclosed spaces which could pose a risk of explosion of asphyxiation. However, there were no exceedances identified for groundwater vapour and given the limited historical development of the area surrounding the Site and the nature of the proposed road scheme. The risk to future infrastructure and services is therefore considered to be Low.

9 Preliminary Waste Assessment

9.1.1 A preliminary waste classification (for off-site disposal to landfill) of selected soil samples was undertaken using the HazWasteOnline^{tm} software tool. WSP has assumed a worst-case scenario to provide an indicative assessment of the material that will be excavated during the development. The waste classification report is presented in **Appendix H**.

9.1.2 Of the forty-two samples submitted for assessment and all were classified as non-hazardous. A summary provided in in **Table 9-1** below.

Table 9-1 Summary of preliminary waste classification

Strata	Number of samples	Preliminary classification	depth Range (m bgl)
Topsoil	13	Non - Hazardous	0.20 to 0.80
Made Ground	1	Non - Hazardous	0.50
Alluvium	2	Non-Hazardous	1.0 to 2.0
Sheringham Cliffs Formation	23	Non - Hazardous	0.50 to 3.0
White Chalk Subgroup	3	Non - Hazardous	0.60 to 2.0

9.1.3 In addition, eleven soil samples, were submitted for Waste Acceptance Criteria (WAC) analysis. Of the soil samples submitted for analysis, one was from the Topsoil, one from the Alluvium and nine were from the Sheringham Cliffs Formation strata. The WAC testing summary is shown in **Table 9-2**.

Table 9-2 Summary of WAC testing

Exploratory hole	Depth (m bgl)	Strata	Hazwasteonline classification	Landfill classification
BH001	1.0	Alluvium	Non-hazardous	Inert
BH003	0.9	Sheringham Cliffs Formation	Non-hazardous	Inert
BH004	2.0	Sheringham Cliffs Formation	Non-hazardous	Inert
BH006	0.5	Sheringham Cliffs Formation	Non-hazardous	Stable non-reactive hazardous waste (If geotechnically suitable)
WS103	3.0	Sheringham Cliffs Formation	Non-Hazardous	Inert
WS107	0.5	Topsoil	Non-hazardous	Stable non-reactive hazardous waste (If geotechnically suitable)
WS108	1.20	Sheringham Cliffs Formation	Non-hazardous	Inert

Exploratory hole	Depth (m bgl)	Strata	Hazwasteonline classification	Landfill classification
WS109	0.80	Sheringham Cliffs Formation	Non-hazardous	Inert
WS110	0.30	Sheringham Cliffs Formation	Non-hazardous	Inert
TP401A	1.0	Sheringham Cliffs Formation	Non-hazardous	Inert
TP402A	2.0	Sheringham Cliffs Formation	Non-hazardous	Inert

9.1.4 From the eleven WAC samples nine were classified as suitable for an inert waste landfill and two for stable non-reactive hazardous waste landfill.

9.1.5 Full WAC results are presented in **Appendix C**.

9.1.6 It should be noted that the above assessment is preliminary and only provides an indication of the likely waste category. The waste producer must also undertake their own classification of material for off-site disposal.

9.1.7 Any waste accepted to a landfill is at the landfill operator's discretion based on the requirements of the licence and further testing will be required.

9.1.8 A Materials Management Plan (MMP), in accordance with CL:AIRE Definition of Waste: Code of Practice or similar, should be implemented if site won material is required for re-use on site and to minimise the quantity of material requiring off-site disposal.

10 Conclusions

10.1 Site Setting

10.1.1 The Proposed Scheme comprises a new approximately 5.7km dual carriageway road from the Broadland Northway (A1270) (formerly Norwich Northern Distributor Road) / Fakenham Road (A1067) intersection at the northern extents of the scheme, to the A47 at the southern extents of the scheme.

10.1.2 Mapping from ca. 1882-1884 suggest that the Site comprised multiple agricultural fields and is crossed by multiple plantations and roads / tracks. Throughout the 20th century, the area has stayed relatively unchanged. There are multiple marl and clay pits in close proximity that have been infilled in the 1970's.

10.1.3 The surrounding area is predominantly agricultural or wooded land with occasional residential properties and farm buildings. Multiple villages are also present within the vicinity of the Site: Attlebridge to the north; Ringland to the east; Honingham to the south; and Weston Green and Weston Longville to the west. The Weston Green solar farm also lies to the west. The River Wensum and associated flood plain roughly runs from north-west to south-east crossing the Site in the northern section.

10.1.4 The geology underlying the site comprises potential Made Ground, Alluvium, Head Deposits, River Terrace Deposits, Sheringham Cliffs Formation, Lowestoft Formation, Happisburgh Glacigenic Formation and White Chalk Subgroup. Alluvium and Head Deposits are classified as Secondary B River Terrace Deposits, Sheringham Cliffs Formation is classified as Secondary A Aquifer. Lowestoft Formation is classified as Secondary Undifferentiated Aquifer and the White Chalk Subgroup is classified as a Principal Aquifer Aquifers by the Environment Agency (EA). There is the potential for groundwater to be present in Made Ground deposits, however it is considered unlikely to be a continuous groundwater body, but rather localised pockets of perched water that are likely to be recharged by surface water infiltration.

10.1.5 Made Ground is likely to be present in the north of Site due to historical development, however the thickness and composition are likely to be highly variable. Groundwater may be present as perched water within the Made Ground, associated with lenses of permeable material which are recharged by surface water infiltration.

10.1.6 The underlying chalk bedrock has been classified as a Principal Aquifer. Groundwater is anticipated to present within the Chalk, at approximately 14.60 m to 15.50 m bgl, based on information recorded on historical borehole logs. Within historic borehole logs, groundwater was not encountered within the superficial deposits, however, should groundwater be present within superficial deposits, it is likely that it will be in hydraulic continuity with groundwater within the Chalk aquifer.

10.2 Site Investigation

10.2.1 The intrusive site investigation was undertaken in two phases by James and Milton Drilling Limited between 20th August 2019 to 8th November 2019 and from 17th August 2020 and 22nd September 2020. The intrusive ground investigation works comprised comprising thirteen cable percussive boreholes eight of them with rotary core follow on, fifteen windowless sample boreholes and six trial pits. Ground gas monitoring of the installed borehole wells was monitored on up to thirty-two occasions between 24 September 2019 and 4 August 2021.

10.2.2 Surfacing of topsoil was present across the majority of the locations across land regularly used for farming with Made Ground and Sheringham Cliffs Formation encountered at two locations and one location respectively. These were underlain by Made Ground deposits in three exploratory hole locations. The Made Ground extended to a thickness of 0.7m and noted adjacent to the southern point of the proposed link road. Where penetrated, the Made Ground was underlain by the Head Deposits and Sheringham Cliffs Formation with thickness ranging between 1.20 m - 4.9 m and ranging from 1.9 m to 30.1 m.

10.2.3 Alluvium was encountered in six locations to a maximum depth of 15.5m bgl encountered in BH016. Four of these were located in close proximity to the River Wensum and its tributaries.

10.2.4 All fifty-four locations penetrated the superficial deposits and twenty-two locations encountered the White Chalk Subgroup. Where proven, the Chalk was encountered in in the deeper boreholes and within some trial pits with thicknesses ranged between 0.8 m – 37.5 m.

10.2.5 In summary, groundwater strikes were recorded at depths between 1.5 and 18.0m in the Sheringham Cliffs Formation. The shallow groundwater strikes at BH012 and BH019 are likely attributed to being in close proximity to the floodplain of the River Wensum and its tributaries in the east of the development. Similarly, the shallow strikes within the Alluvium (BH014 - BH016) are likely associated with the floodplain of the River Wensum. Based on the similar geologies and strikes encountered within the floodplain, it is considered the Alluvium and Sheringham Cliffs Formation may be in hydraulic continuity.

10.2.6 There were no recorded visual and olfactory signs of contamination observed during the investigation. However, outside of the investigation (in September 2019), a suspected sheet of corrugated asbestos roof panel was identified during an ecology walkover in an area of woodland to the south-east of BH110 and north of Ringland Lane. The panel was found intact and approximately 350m to the south-east of the proposed development.

10.2.7 Ground gas monitoring was undertaken on thirty-two occasions and groundwater sampling was undertaken on six occasions.

10.3 Risk Assessment

10.3.1 A Generic Quantitative Risk Assessment (GQRA) was undertaken considering the current site layout and the potential proposed development of the site as a proposed road scheme, and potential future receptors.

10.3.2 Based on the findings of the assessment the following conclusions are made:

Human Health

10.3.3 Compared against highways screening criteria, there are no exceedances of the GAC.

10.3.4 Asbestos fibres were not detected in any of the tested samples. However, it should be noted that during an WSP ecology walkover (outside the scope of the ground investigation) in September 2019, a suspected sheet of corrugated asbestos roof panel was identified in an area of woodland to the south-east of BH110 and north of Ringland Lane. The panel was found intact and approximately 350m to the south-east of the proposed development.

10.3.5 Given the heterogeneous nature of the Made Ground deposits and the former land uses identified at the Site, the presence of asbestos within Made Ground in other areas of the Site cannot be discounted. However, the proposed highways land use includes the site being covered by hardstanding, therefore removing the pathway to future site users and third-party neighbours.

10.3.6 It should be noted that if asbestos were to be identified during development, a **Low to Moderate** risk would be present if the material is re-used in soft landscaped areas (i.e. embankments). Material would need to be managed under a wider Materials Management Plan (MMP) to ensure the suitability for re-use. An appropriate level of chemical testing and risk assessment should be undertaken to assess the suitability for re-use on site. Following mitigation, the risks in unsealed areas are considered to be **Low**.

10.3.7 The risks should be managed through the appropriate use of Personal Protective Equipment (PPE) and Respiratory Protective Equipment (RPE). Good construction practices (i.e. dust suppression, wheel washing) should be utilised to manage the risks to third party neighbours during construction phases. Guidance presented in CIRIA 733 “Asbestos in soil and made ground: a guide to understanding and managing risks” should be consulted when managing risks arising from asbestos.

10.3.8 Based on the evaluation above, the risk to human health is considered to be **Low**.

10.3.9 When compared against the groundwater vapour commercial screening criteria, there are no exceedances of the GAC. Therefore, the risk to human health from groundwater vapour is considered to be **Low**.

10.3.10 There is no considered to be a risk to human health from groundwater vapour. The risk to construction / maintenance workers from inhalation of vapours within the shallow groundwater is considered to be Low.

10.3.11 The risk to human health from off-site sources is considered to be **Low**.

Controlled Waters

10.3.12 Based on the assessment of the soil leachate and groundwater results, the risk to groundwater in the Alluvium, Sheringham Cliffs Formation and Chalk underlying the Site are considered to be Low. Risk to the River Wensum and tributaries from groundwater within the superficial deposits underlying the Site is considered to be Low.

10.3.13 This assessment is based upon the following:

- There are no sources of potential contamination identified such as contaminated Made Ground.
- The leachate exceedances are marginal and are likely to be associated with background concentrations of contaminants within the natural strata underlying the Site.
- The Site is proposed to be covered in hardstanding at the road surface which would provide betterment and reduce infiltration of rainwater into the ground and therefore limit the mobilisation of potential contaminants of concern.
- Based on there being no historical development across the Site and limited Made ground deposits identified on the Site, the contaminants of concern are considered likely to be associated with background concentrations within the underlying natural strata and / or the regional groundwater quality of the local area.

- Exceedances of EQS in the Alluvium are noted within boreholes in close proximity to the River Wensum. These are thought to be related to surrounding widespread leaching of soils. Additionally, groundwater levels in these boreholes were shallow and, on some occasions, flooded completely to ground level which would suggest that surface water may have impacted groundwater in the underlying Alluvium.
- Regarding DWS exceedances, there are no groundwater abstractions utilised for the abstraction of drinking water located within the vicinity of the Site.

Ground Gas

10.3.14 Deplete oxygen concentrations were not recorded during the twelve monitoring visits, with concentrations recorded to range from 12.7% (v/v) to 21.0% (v/v).

10.3.15 With respect to data suitability, for a low sensitivity end use (commercial - road) and low source generation, CIRIA C665 recommends a minimum of six ground gas monitoring visits over a period of two months. CIRIA C655 also recommends that ground gas monitoring is undertaken during low (<1000 mb) and falling pressure conditions since this is considered to represent a worst-case scenario. As such, it is considered that these minimum requirements have been met by the monitoring.

10.3.16 Deplete oxygen concentrations were not recorded during the twelve monitoring visits, with concentrations recorded to range from 12.7% (v/v) to 21.0% (v/v). No carbon monoxide, PID readings or hydrogen sulphide readings were taken during the monitoring rounds.

10.3.17 No carbon monoxide, PID readings or hydrogen sulphide readings were taken during the monitoring rounds.

10.3.18 Based on the monitoring data, a maximum GSV of 0.00 l/hr was calculated for methane, and a maximum GSV of 0.007 l/hr was calculated for carbon dioxide. These maximum values do not exceed the 0.07 l/hr limit for

Characteristic Situation 1 for methane or carbon dioxide. However, carbon dioxide concentrations at WS110 (installed in Chalk), exceeded 5 % v/v during monitoring rounds; therefore, CIRIA C665 guidance suggests an upgrade to Characteristic Situation 2 (**Low Risk**).

10.3.19 However. it should be noted that the proposed development is a proposed road scheme, the use of the CIRIA 665 assessment is not strictly appropriate. Risks to construction and maintenance workers from ground gas are recommended to be managed through health and safety protocols.

Preliminary Potable Water Supply Pipe Assessment

10.3.20 Based on the available data and the preliminary assessment, barrier pipes are considered to be required if pipes are to be installed within Made Ground deposits. However, it should be noted that this is a preliminary assessment, and any pipe design should be subject to the appropriate testing in service trenches and agreed with the relevant statutory authority.

Preliminary Phytotoxicity Assessment

10.3.21 Based on the average of results from samples obtained during the initial investigation, no exceedances of the MAFF values were noted. As such, an overall phytotoxic risk to plants is considered to be **Low**.

11 Recommendations

11.1.1 Based on the findings of the GQRA, the following recommendations are made in order to mitigate potential risks associated with the potential contaminants of concern identified:

- Asbestos containing materials have not been noted as being present on the site, but suspected ACMs have been noted offsite and outside the scope of this investigation approximately 350m south-east of BH110. Given the heterogeneous nature of the Made Ground deposits and the former land uses identified at the Site, the presence of asbestos within Made Ground in other areas of the Site cannot be

discounted. During the construction phases of the development, the risks to construction workers should be managed through the appropriate use of PPE and RPE. Good construction practices (i.e. dust suppression, wheel washing) should be utilised to manage the risks to third party neighbours during construction phases. Guidance presented in CIRIA 733 “Asbestos in soil and made ground: a guide to understanding and managing risks” should be consulted when managing risks arising from asbestos;

- If site-won material is to be reused on the Site, this should be undertaken in accordance with a Materials Management Plan (MMP), in accordance with CL:AIRE Definition of Waste: Code of Practice or similar, should be implemented if site won material is required for re-use on site and to minimise the quantity of material requiring off-site disposal;
- A preliminary potable water pipe assessment indicated that barrier pipes may be required at the Site, however, further testing and assessment should be undertaken in consultation with utility providers; and
- A Remediation Strategy incorporating the recommendations should be produced which includes an options appraisal of the risks identified and the measures required to mitigate the risk;

11.1.2 Should development plans change or be altered, an update of the assessments undertaken within this report are likely to be required.