A12 Chelmsford to A120 widening scheme

TR010060

6.3 ENVIRONMENTAL STATEMENT

APPENDIX 10.1 LAND QUALITY RISK ASSESSMENT

APFP Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Volume 6

August 2022

Infrastructure Planning

Planning Act 2008

A12 Chelmsford to A120 widening scheme

Development Consent Order 202[ ]

ENVIRONMENTAL STATEMENT APPENDIX 10.1 LAND QUALITY RISK ASSESSMENT

Regulation Reference	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference	TR010060
Application Document Reference	TR010060/APP/6.3
Author	A12 Project Team & National Highways

Version	**Date**	**Status of Version**
Rev 1	August 2022	DCO Application

CONTENTS

LIST OF PLATES

LIST OF TABLES

1 Executive summary

1.1.1 The A12 Chelmsford to A120 widening scheme (the 'proposed scheme') comprises improvements to the A12 between junction 19 (Boreham interchange) and junction 25 (Marks Tey interchange), a distance of approximately 24km, or 15 miles. The proposed scheme involves widening the A12 to three lanes throughout (where it is not already three lanes) with a bypass between junctions 22 and 23 and a second bypass between junctions 24 and 25. It also includes safety improvements, including closing off existing private and local direct accesses onto the main carriageway, and providing alternative provision for walkers, cyclists and horse rides (WCH) to existing routes along the A12, which would be removed.

1.1.2 Where the footprint of the proposed widening is constrained, retaining structures would be required. The proposed scheme would include replacement and new bridges and culverts. Attenuation ponds would be constructed to accommodate increased surface water runoff and borrow pits would be excavated to provide additional material for embankment construction.

1.1.3 The proposed scheme is divided into three design sections numbered 1 to 3 from south (junction 19) to north (junction 25). Intrusive ground investigations (GI) were undertaken in three phases (1 to 3), generally aligned with the scheme design section extents. The Phase 1 ground investigation (GI) included all the borrow pit areas initially proposed however, not all of these borrow pits have been taken forward within the proposed scheme.

1.1.4 This Land Quality Risk Assessment (an appendix to Chapter 10: Geology and soils of the Environmental Statement [TR010060/APP/6.1]) includes the findings of the geo-environmental aspects of the Phases 1, 2 and 3 GI.

1.1.5 The superficial geological sequence underlying the proposed scheme consists of variable Head Deposits underlying River Terrace Deposits which are generally comprised of sands and gravels. Variable Alluvial deposits generally consisting of soft clays and silts can be found in river valleys overlying Head and River Terrace Deposits. The GI indicates Alluvium has been removed from beneath the existing A12 alignment. These materials overlay a sequence of glacial and periglacial deposits consisting of the Interglacial Silts and Clays, Lowestoft Formation (Glacial Till), often interbedded with Glaciofluvial Deposits (sand and gravels) and Glaciolacustrine Deposits (laminated silt and clay). The glacial materials are underlain by London Clay Formation, consisting of stiff clay along design section 1 and 2 of the proposed scheme with Kesgrave Gravels (sand and gravel) found between the glacial materials and London Clay Formation along design section 3. A buried channel underlies parts of design section 2 and design section 3 and contains Lowestoft Formation at significant depth, including interbeds of Glaciolacustrine silts and clays.

1.1.6 The existing A12 embankments are indicated to be generally constructed of a mix of compacted granular and cohesive fill.

1.1.7 There are records of historical landfills within 250m of the proposed scheme. The proposed scheme would encroach on the boundaries of some of these landfills at Witham between junction 21 and 22 (design section 2) including

Blackwater Lane landfill, Perry Road and East of Railway Line landfills, which are phased landfills operated in the same area within Whetmead Local Nature Reserve (LNR), referred to in this report as Whetmead LNR Witham landfill and London Road landfill located to the south-east of junction 25.

1.1.8 Groundwater is found throughout the proposed scheme at shallow depth in granular superficial deposits and within granular lenses/beds within cohesive glacial material and the London Clay Formation. Ground water levels within the superficial deposits were not consistent and therefore a potentiometric surface could not generally be determined. However, groundwater flow was indicated to generally follow topography and to be towards the main rivers as would be expected.

1.1.9 The primary geo-environmental risks identified within the proposed scheme and borrow pits are:

- Land contamination risk to human health - the GI has identified potential risk from soil contamination to on-site workers (construction workers and future maintenance workers) and the public during construction work, but the findings indicate the risk is considered to be generally low.

- Land contamination risks to controlled water receptors – the GI has identified elevated concentrations of contaminants within the existing groundwater beneath and adjacent to the scheme and borrow pits indicating generally poor groundwater chemical quality conditions. Where groundwater control is required, discharge to existing surface waters must be under an Environment Agency permit or discharge consent. Groundwater and surface water management plans would be produced in the second iteration of the EMP. Further Detailed Quantitative Risk Assessment (DQRA) would be undertaken for the management of any dewatering and to support a permit for discharge if required. There is potential for further contamination of groundwater through contaminants that may be mobilised during construction requiring adequate control measures to be put in place prior to the proposed works. Monitoring of groundwater during and post construction works would be undertaken to assess the impact of the scheme on baseline conditions.

- Fill materials – Soil leachability assessment undertaken indicates that elevated concentrations of leachable contaminants are present in soils underlying the scheme and the borrow pits. Any fill materials to be used on the proposed scheme would be determined suitable for reuse by the adoption of an appropriate acceptability criteria derived from a DQRA.

2 Introduction

2.1.1 The A12 Chelmsford to A120 widening scheme (the 'proposed scheme') comprises improvements to the A12 between junction 19 (Boreham interchange) and junction 25 (Marks Tey interchange), approximately 24km, or 15 miles. The proposed scheme involves widening the A12 to three lanes throughout (where it is not already three lanes) with a bypass between junctions 22 and 23 and a second bypass between junctions 24 and 25. It also includes safety improvements, including closing off existing private and local direct accesses onto the main carriageway, and providing alternative provision for walkers, cyclists and horse rides (WCH) to existing routes along the A12, which would be removed.

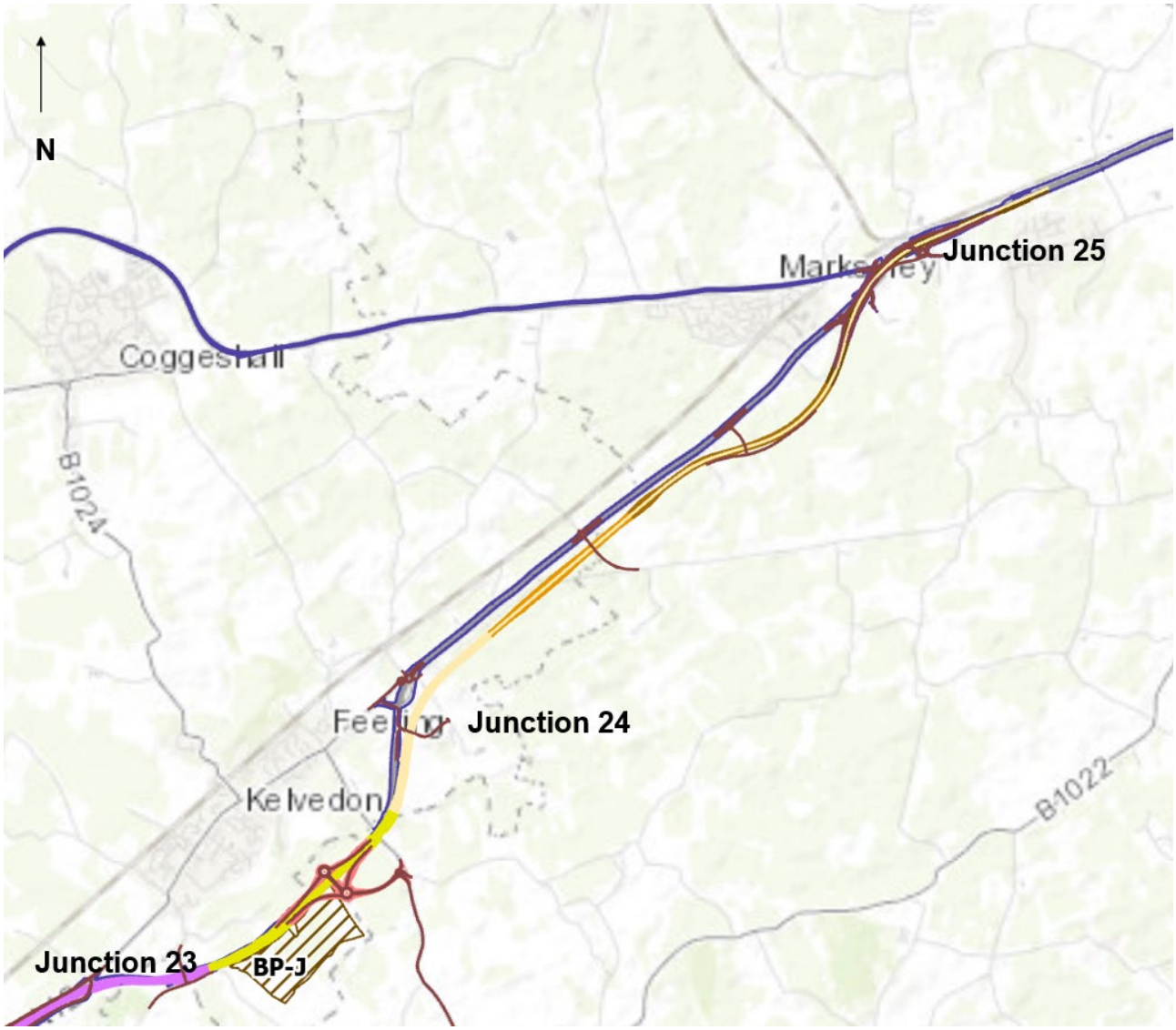
2.2 Description of the proposed scheme

2.2.1 Detailed description of the proposed scheme is available in Chapter 2: The proposed scheme, of the Environmental Statement [TR010060/APP/6.1]. The general configuration and alignments are presented in Plates 2.1, 2.2 and 2.3 below.

Plate 2.1 Mainline design section 1 – junctions 19 to 21 (including borrow pits)

Plate 2.2 Mainline design section 2 - junction 21 to 23 (including borrow pits)

Plate 2.3 Mainline design section 3 - junctions 23 to 25 (including borrow pits)



2.2.2 The information detailed in this report have been extracted from the Geotechnical Investigations Reports (GIR) prepared for Phases 1 to 3 of the GI.

2.2.3 This assessment includes only the four borrow pits which have been selected following the GI of the borrow pit locations originally considered for the proposed scheme. The findings of the GI undertaken relevant to this assessment are summarised in Section 6 of this report.

2.3 Scope and objectives of this report

2.3.1 The objectives of this Land Quality Risk Assessment are to:

- Carry out a preliminary human health and controlled waters risk assessment
- Carry out preliminary waste classification assessment for the proposed scheme

- Highlight key land contamination risks requiring consideration during design development

2.3.2 This report provides a summary of the findings of the geo-environmental aspects of the ground investigation undertaken for the proposed scheme and the baseline ground conditions identified as part of the Preliminary Sources Report.

2.4 Exclusions and assumptions

2.4.1 This report is authored with the following assumptions and exclusions:

- This assessment includes the geo-environmental aspects of the proposed scheme Phases 1 to 3 GIR (including borrow pits). The Phase 3 Association of Geotechnical and Geo-environmental Specialists (AGS) data has some limited laboratory test data missing and a complete set was not available at the time of writing this report. However, there is sufficient data to enable interpretation and assessment of geo-environmental risks detailed in this report. The full data set will be utilised during the detailed design.
- It should be noted that the GI was undertaken at an earlier stage in the design process and there have been changes to the design since then. A gap analysis is currently being undertaken at the time of writing this report based on subsequent design fixes to enable supplementary GI to be designed. Following supplementary GI scoping, a further site-specific GI would be undertaken as part of the Stage 5 detailed design works. The GI data would be utilised for the detailed design.
- Detailed considerations relating to temporary works are outside the scope of this report.
- Details of archaeological and ecological constraints were considered in the planning and execution of the GI.
- Geological units and data presented in this report are considered a reasonable approximation to the actual geology encountered. Further review of the ground conditions underlying the proposed scheme and refinement of the ground model will be undertaken during detailed design.
- Strata beneath the London Clay Formation has not been considered as it is deeper strata and is unlikely to be affected by the proposed scheme.
- Only limited groundwater monitoring data was available at the time of writing this report. Further seasonal variation may therefore be found, which has not currently been identified by the current monitoring data. This would be reviewed and updated during detailed design.

3 Existing information

3.1 Introduction

3.1.1 The following is a summary of relevant information available for the proposed scheme.

3.2 Topographic surveys

3.2.1 The scope of site-specific surveys commissioned for the proposed scheme were as follows:

2017 surveys - mainline

- Site specific aerial mapping and LiDAR data was captured by Cyient in May 2017 and adjusted to ground controls surveyed by Jacobs using Terrestrial Survey Instruments (Global Navigation Satellite System (GNSS) and total stations). Resultant mapping for the aerial survey areas conformed to required accuracy of: height (z) +/-40mm and plan (x,y) +/-80mm for 'hard' features. These accuracies are doubled for "soft" features.
- Carriageway mapping data utilised existing National Highways mobile LiDAR data post-processed to Jacobs' ground control. Online carriageway data produced to within 10mm Root mean Squared Error (RMSE).

2020 surveys

- Additional aerial mapping and LiDAR data captured by Cyient in February/March 2020 and adjusted to ground control surveyed by Jacobs using terrestrial survey instruments (GNSS and total stations). This covered additional LiDAR areas for the borrow pits and full area refresh of aerial imagery to the same accuracy as the 2017 surveys.

3.2.2 Both the 2017 and 2020 surveys were completed to the following specification:

- LiDAR data at a density of 50ppm
- Imagery at 2.5cm resolution delivered as orthophoto tiles
- Digital Terrain and Digital Surface Model (DTM/DSM) tiles in LAS and TXT formats in OSGB coordinate system
- 1:500 scale topographic mapping
- National & Local Grid (IANS 99/07)
- AutoCAD & MX formats
- Accuracy of Lidar and Mapping to be 30mm RMSE
- Data produced with an accompanying survey report

3.2.3 Jacobs has also obtained Lidar DTM contours on z,x y+/-1m scale from the Environment Agency.

3.2.4 A summary of the topography along the proposed scheme is presented in Table 3.1. The chainages are shown on the General Arrangement Plans [TR010060/APP/2.9]. Further detailed topographic analysis will be undertaken during detailed design.

Table 3.1 Summary of topography along the proposed scheme

Location	Topographic detail
Design section 1	
CH 09+500 to CH11+850	The carriageway lies at approximately 31mAOD in cut with the surrounding junction reaching 34mAOD approximately. The junction itself is located on a hillside, with higher ground to the north west and lower ground to the south east.
CH15+400 to 15+550	To the east, the initial elevation of the road at the start of the proposed widening works is 22mAOD approximately along the mainline. The alignment is this area is located in a gentle valley feature. Orientated north west and containing a small river.
CH15+550 to 16+750	The road rises up an incline to an elevation 41mAOD in the town of Hatfield Peveril which lies at the top of a hill
CH16+750 to 18+000	Existing junctions 20 and 21 and proposed combined junction 20-21 are located to the north east of Hatfield Peveril, parallel to a hillside reaching 51AOD to the north west and 38mAOD to the south east with an existing carriageway elevation of approximately 43mAOD. The ground to the south east is comprised of lower lying with open fields and ponds.
CH18+000 to 19+500	The mainline then moves downhill to the east, skirting the southern perimeter of Witham decreasing in elevation from approximately 41mAOD to approximately 19mAOD. Design section 1 ends aligned perpendicular to the hill slope Witham is constructed on to the north. With a valley to the south with a base elevation of 15mAOD.
Design section 2	
CH19+589	The design section 2 mainline begins south of Witham at an elevation of approximately 20mAOD at mainline level parallel to the hillside on which Witham is constructed.
Ch20+500	The road is raised on embankment of elevation 22mAODover a bridge at CH 20+500 and a further bridge over a river valley at CH 21+150.
CH21+150-CH22+500	The alignment turns to north continuing to follow the contours around Witham Hill and moving into the Blackwater River valley. The alignment heads north adjacent to the valley floodplain to the east (with the eastern valley walls and the town of Little Braxted beyond) and Witham to the west and the western slopes of the valley. The alignment moves from a low of 16mAOD at CH 21+450 to 19 at CH 22+500 as it passes through the valley.

Location	Topographic detail
CH 22+600.	The route continues to move north up the valley reaching an elevation on the mainline of 21mAOD approximately at junction 22. The proposed section of junction 22 is to be constructed on a river terrace within the valley at an elevation of approximately 18mAOD, with a steep hill to the north-west.
CH24+000	After junction 22 ends the alignment continuous to the north east moving up the valley walls to an elevation of approximately 22mAOD and crossing a river valley at CH 24+500.
CH26+250 (Blackwater River)	The alignment continues along the valley wall parallel to the northern hill slope at 22mAOD until it crosses over to the eastern side of the valley, over the Blackwater river (18mAOD) on an embankment of 24mAOD elevation.
CH26+250 to 30+000	The alignment continues north -east up the eastern side of the valley at an approximate elevation of 25mAOD with a narrow flood plain to the west at 20mAOD approx. and parallel to the valley slope to the east which reaches an elevation of over 70mAOD.
Design section 3	
CH30+000	Design section 3 begins at approximate mainline elevation of 27mAOD and is located on the eastern side of the River Blackwater valley, with floodplain located 300m to the north west at 20mAOD and the valley slope rising to 70mAOD to the south east.
CH30+750 to 31+700 approximately	The alignment rises to an elevation of 32mAOD at junction 24
CH31+800	The route crosses a small tributary river valley an elevation of 25mAOD at CH 31+750m approx. and deviates from the existing A12 to the north east.
CH31+800 to CH+34+750	The route continues adjacent to the existing A12, heading to the north east, as the River Blackwater valley deviates to the north west. The route passes over a series of small troughs and rises from 25mAOD to 31mAOD.
CH+34+750 to35+500	The alignment reaches 42mAOD along the mainline approximately on a small hill at before crossing a small valley at CH 35+500 with an elevation of 35mAOD. Another small valley lies 300m to the south east of the route with a base of 28m approximately and higher ground lies to the north west of the route at between 40 and 50mAOD approximately.
35+500 to 38+000	The route, continuing to the north east climbs to an elevation of 44mAOD at CH 37+500 500m east of the village of Marks Tey. The route then re-joins the A12 at junction 25 which lies on a small hill with an approximate elevation of 40mAOD, with small valleys to the north and south east leading away from the route alignment.
38+000 to 39+35	Design section 3 terminates at CH 39+355, heading north east into the northern valley to an elevation of 31mAOD approximately.

3.3 Aerial photographs

3.3.1 As discussed in Section 3.2 of this report, aerial photography was provided at a 2.5cm resolution concurrently with the 2017 and 2020 LiDAR surveys. The aerial imagery was used to identify current and possible historical features, vegetation/tree cover, land use, other surface features and potential access in order to assist with the placement of ground investigation locations. In addition to the Jacobs commissioned surveys, the assessment included images from the following sources:

- Data purchased for the project, including a Landmark Envirocheck report and Groundsure report
- Publicly available aerial imagery (dated 2017)
- Satellite and aerial imagery available from ArcGIS (i.e., Esri World Imagery Map) which dates from 1999 (low resolution) to 2011 (high resolution)
- All relevant information from these sources has been included in this report or Chapter 10: Geology and soils of the Environmental Statement [TR010060/APP/6.1]

3.4 Geological maps and memoirs

3.4.1 Geological information was reviewed. The main sources of data reviewed were from the British Geological Survey (BGS). These are summarised in Table 3.2 below.

Table 3.2 British Geological Survey data sources

Source	Reference
BGS Geological Maps	• 1:50,000 Sheet 241 Chelmsford (Solid and Drift Edition, 1975) • 1:50,000 Sheet 223 Braintree (Solid and Drift Edition, 1982)
BGS Geological Memoirs	• The geology of the country around Chelmsford, Sheet 241, Bristow 1985 • The geology of the country around Braintree, Sheet 223, Ellison 1986
BGS – Other Data	• GeoIndex

3.4.2 The general stratigraphy expected consists of a combination of Quaternary superficial deposits overlying bedrock geology including London Clay Formation, Lambeth Group, Thanet Sand and Chalk. The Quaternary superficial deposits where present include a combination of; Alluvium, River Terrace Deposits, Head Deposits, Brickearth, Interglacial Lacustrine Deposits, Glaciolacustrine Deposits, Lowestoft Formation, Glaciofluvial Deposits and Kesgrave Catchment Subgroup. The geological maps indicate a buried (drift-filled) channel beneath the majority of design section 2 and the western half of design section 3.

3.4.3 The 1975 and 1982 geological maps present now superseded drift and solid geology stratigraphic terminology. Current superficial (formerly drift) and bedrock (formerly solid) terminology is presented within the online BGS Geology of Britain Viewer and Lexicon of Named Rock Units. Table 3.3 presents a summary of the superseded and current terminology.

Table 3.3 British Geological Survey geological units

<table>
<tr><th></th><th colspan="2">Sheet 241 (1975) geological map</th><th colspan="2">Sheet 223 (1982) geological map</th><th></th><th>BGS Geology of Britain Viewer and lexicon of named rock units</th></tr>
<tr><td rowspan="10">Drift</td><td colspan="4">Alluvium</td><td rowspan="10">Superficial</td><td>Alluvium</td></tr>
<tr><td colspan="4">River Terrace Deposits</td><td>River Terrace Deposits</td></tr>
<tr><td colspan="4">Head</td><td>Head Deposits</td></tr>
<tr><td colspan="2">Brickearth</td><td colspan="2">N/A</td><td>Brickearth</td></tr>
<tr><td colspan="4">Lacustrine Deposits</td><td>Interglacial Lacustrine Deposits</td></tr>
<tr><td colspan="2">Lake Deposits</td><td colspan="2">N/A</td><td>Glaciolacustrine Deposits</td></tr>
<tr><td colspan="4">Boulder Clay</td><td>Lowestoft Formation</td></tr>
<tr><td colspan="4">Glacial Sands and Gravel</td><td>Glaciofluvial Deposits</td></tr>
<tr><td colspan="2">N/A</td><td colspan="2">Kesgrave Sands and Gravel</td><td>Kesgrave Catchment Subgroup</td></tr>
<tr><td rowspan="4">Solid</td><td colspan="4">London Clay</td><td rowspan="4">Bedrock</td><td>London Clay Formation</td></tr>
<tr><td colspan="2">Woolwich & Reading Beds</td><td colspan="2" rowspan="2">Lower London Tertiaries</td><td rowspan="2">Lambeth Group(1)</td></tr>
<tr><td colspan="2">Thanet Beds</td></tr>
<tr><td colspan="4">Upper Chalk</td><td>Chalk(1)</td></tr>
<tr><td colspan="7">Notes
(1) These materials have not been proven by GI in the site area as of this issue of this report.</td></tr>
</table>

3.4.4 The anticipated geology along each design section was based on data sourced from BGS historical logs and memoirs where available. This information is summarised below in Table 3.4. The anticipated geology underlying the proposed scheme has been further refined using data from the current GI of the proposed scheme and is detailed in Section 4 of this report. The relevant information from the BGS digital geological mapping is shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].

Table 3.4 Anticipated geology along the proposed scheme derived from BGS mapping

Location	Post glacial superficial geology	Glacial superficial geology	Bedrock geology
Design section 1			
CH 09+500 to 10+350	Alluvium and River Terrace Deposits in river channel.	Glaciofluvial Deposits overlying Lowestoft Formation.	London Clay Formation
CH 10+350 to 11+550	Head Deposits and small alluvial channel to the east.	Glaciofluvial Deposits overlying Glaciolacustrine Deposits.	
CH11+550 to 15+400	River Terrace Deposits to the east. Head beyond CH 15+100.	Lowestoft Formation overlying Glaciofluvial Deposits.	
CH 15+400	Alluvial channel	Glaciofluvial Deposits overlying Glaciolacustrine Deposits.	
CH 15+450 to 16+500	N/A	Glaciofluvial Deposits overlying Glaciolacustrine Deposits.	
CH 16+500 to 19+500	N/A	Lowestoft Formation overlying Glaciofluvial Deposits and Glaciolacustrine Deposits.	
Design section 2			
CH 19+500 to 21+100	River Terrace Deposits	N/A	London Clay Formation
CH 21+100 to 21+150	Alluvial Deposits overlying River Terrace Deposits	N/A	
CH 21+150 to 24+400	Alluvium between CH 21+750 to 22+200 overlying River Terrace Deposits	Lowestoft Formation overlying Glaciofluvial Deposits. Entering buried channel of deeper glacial / interglacial deposits at CH 21+750.	
CH 24+400 to 24+500	Alluvium	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits.	
CH 24+500 to 25+500	Alluvial Channel at CH 24+550	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits.	

Location	Post glacial superficial geology	Glacial superficial geology	Bedrock geology
CH 25+500 to 27+000	CH 26+250 to 26+300 Alluvial channel CH 25+500 to 26+000 and CH 26+250 to 27+000 River Terrace Deposits	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits.	
Design section 3			
CH 30+000 to CH 31+900	Alluvial Channel at CH 30+000 to 30+030. River Terrace to CH 30+500, the sporadic islands of River Terrace Deposits to CH 31+500.	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits.	London Clay Formation
CH 31+900 to 32+000	Alluvium	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits. The Kesgrave Catchment Subgroup may be present.	
CH 32+000 to 32+100	Head	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits. The Kesgrave Catchment Subgroup may be present.	
CH 32+100 to 32+650	River Terrace Deposits	Buried channel of deeper glacial / interglacial deposits, including Lowestoft Formation overlying Glaciofluvial Deposits terminates at CH 32+650. The Kesgrave Catchment Subgroup may be present.	
CH 32+650 to 38+400	N/A	Lowestoft Formation possibly overlying Glaciofluvial Deposits. The Kesgrave Catchment Subgroup may be present.	
CH 38+400 to 39+150	N/A	Kesgrave Catchment Subgroup	

Location	Post glacial superficial geology	Glacial superficial geology	Bedrock geology
CH39+150 to 39+400	Alluvium between CH 39+250 to 39+355.	Glaciolacustrine Deposits overlying Glaciofluvial Deposits.	

3.5 Mineral sites

3.5.1 Detailed information on mineral resources present along the study area and the potential effects of the proposed scheme on mineral resources are assessed within Chapter 11: Material assets and wastes, of the Environmental Statement [TR010060/APP/6.1].

Historical mineral extraction site (potentially infilled)

3.5.2 Based on available information, there are a number of historical mineral extraction sites within 250m of the proposed scheme including brickfields, gravel pits, sand pits and quarries. Some of the sites have been redeveloped and others appear to be infilled with unknown materials and are therefore considered as potential sources of land contamination. These sites are summarised in Table 3.5 below.

3.5.3 During the GI at borrow pit J, an infilled gravel pit was identified which had been backfilled with waste materials including suspected asbestos-containing materials (ACM).

Table 3.5 Potentially infilled historical mineral extraction sites within 250m of proposed scheme

Historical mineral extraction sites	Current status	Distance from the proposed scheme		Current land use
		Online sections	Offline sections	
Junction 19 to 20				
Boreham House gravel pit	Inactive	20m north	No offline section	Agricultural
Historical Hogwells brickfield	Inactive	On route and extends 140m to the south of the proposed scheme	No offline section	Residential properties shown on the footprint.
Junction 20 to 21				
Historical brick works at Hatfield Peverel	Inactive	8m north	No offline section	Residential (southern section). Northern section is undeveloped.

Historical mineral extraction sites	Current status	Distance from the proposed scheme		Current land use
		Online sections	Offline sections	
Historical sand and gravel pit at Hatfield Peverel	Inactive	150m south	No offline section	Landscaped as a lake.
Junction 21 to 22	N/A - None present			
Junction 22 to 23	N/A - None present			
Junction 23 to 24				
Historical gravel pit (Ewell Hall)	Inactive	120m south	No offline section	Undeveloped
Historical brickfield (Brick Kiln / Park farms)	Inactive	On route	No offline section	Existing A12 built on this site. Brickfield extends from the A12 to approximately 200m south of the road.
Historical sand pit (Threshelfords Farm)	Inactive	180m north	No offline section	Redeveloped into Threshelfords business park.
Junction 24 to 25	N/A - None present			
Junction 25 to end of scheme				
Historical Copford borrow pit - mineral extraction site	Inactive	30m south	400m south	Undeveloped
Historical Copford brick works	Inactive	100m south	900m south	Redeveloped as residential area.

Historical infilled land (associated with water)

3.5.4 The Envirocheck report identified two historical areas of infilled land associated with water within 250m of the proposed scheme. However, the proposed scheme is unlikely to be impacted by either of these features and therefore they are not considered further in this report.

3.6 Current and historical land use

3.6.1 Information used to identify current and historical land use and assess risk from a geotechnical and contaminated land perspective is provided in the following documents:

- Data purchased for the project, including a Landmark Envirocheck report and Groundsure report
- Google Maps aerial imagery (dated 2017 to 2020)
- Satellite and aerial imagery available from ArcGIS (i.e. Esri World Imagery Map) which dates from 1999 (low resolution) to 2011 (12.5cm resolution)
- Environment Agency's "What's in Your Backyard" website. This site is no longer available, however, most information previously on this database are now available on the Magic map website.

3.6.2 A review of historical maps of the proposed scheme focussed primarily on the land uses considered likely to be potential sources of contamination and included identification of areas of historical mineral extraction and areas of potentially infilled ground.

3.6.3 The proposed scheme is located within a predominantly agricultural area. The A12 in its current form is shown to have been constructed from around the 1960s to the 1970s. The urban areas of Witham and Chelmsford have developed around the A12, along with the residential towns of Boreham, Hatfield Peverel, Rivenhall End, Kelvedon and Marks Tey. The Great Eastern Railway (GER), which runs parallel with the proposed scheme, has been present from before 1874 until the current day. A number of small garages and fuel stations have been identified within these towns and villages from the 1960s, and by the 1990s many were no longer in use and had been redeveloped. Much of the area surrounding the proposed scheme has also been subject to gravel or sand extraction from before the earliest maps reviewed dated 1874 to around the 1960s.

3.6.4 Table 3.6 contains a summary of major historical land uses along the route. Off route locations are excluded from the summary but are available in the Preliminary Sources Study Report (PSSR).

Table 3.6 Assessment of historical land use

Junction 19 to 20
Existing A12: the A12 from chainage 30+500 was shown on the 1970 – 1979 map. The remaining section of the proposed route before junction 19 (start of the proposed scheme) was shown on maps from 1990 to 1993. Prior to this time both sections were shown as undeveloped on the earliest historical maps in 1874. Historical Hogwells brickfield (TL 76706 10934) chainage 33+500: located on the existing A12 and extends further south of the road, approximately 140m on the corner of Damases Lane and Main Road. Shown as brickfield on the 1874 maps, then brick works in 1897. The brick works are no longer shown from the 1952 – 1953 map. Residential properties are shown on the footprint from 1999.

Junction 20 to 21
Existing A12: the earliest historical map in 1874 shows a road (Roman Road) on the proposed scheme. Part of the proposed scheme from junction 20A to junction 20B was undeveloped in 1875 but was later developed into a residential area in 1955. The developed part was identified as A12 on the 1953 map. Widening of the A12, including the construction of junction 20A and junction 20B was shown on the 1964-1966 map and the 1968 map. No obvious changes were shown on successive maps to present day.
Junction 21 to 22
Existing A12: this section of the A12 was shown as undeveloped on the earliest historical maps in 1874 until the 1966-1969 map when it was shown as a road. No significant changes are shown on successive maps to present day. Great Eastern Railway – Witham to Maldon branch line crossing (TL 82477 13395): this branch of the railway line crosses the A12 just north of the B1018 / A12 crossing. It was shown from the earliest (1874) map and as dismantled on the 1978 map. Witham sewage treatment works (TL 82841 13936): a sewage farm is indicated on the map between the railway line and the site of the existing A12 on the map for 1898. By 1924 the area between the railway line, the River Brain and the site of the existing A12 was labelled as a sewage farm and a number of tanks are shown across the area. Further development of the sewage works is shown on successive maps. By 1971 the A12 has been constructed. The sewage works were still present at this time and are located immediately to the west of the A12. At this time the maps show filter beds, sludge lagoons, and humus tanks to be present to the west of the A12. Tanks, a lagoon and sludge beds are present to the east. By 1980 further tanks are shown within the western part of the sewage works. Also, at this time the whole of the eastern part of the sewage works is shown as a refuse heap/landfill, the lagoon remains present. It is not clear from the maps whether the landfill is associated with the sewage works. No further significant changes are shown until the map for 1999 when the eastern part of the sewage works is shown as a nature reserve, the lagoon is still present. The sewage works remain to the west of the A12 at this time. No further significant changes are shown on the map to the present day.
Junction 22 to 23
Existing A12: A Roman road was shown on the proposed scheme on the earliest map in 1875 with no significant changes until 1955. The road was expanded on the 1966-1969 and 1971-1974 maps. Construction of junction 22, junction 23 and the Rivenhall End junction was also shown during these times. No further significant changes are shown on the map to the present day.
Junction 23 to 24
Historical brick field at Brick Kiln / Park farm (TL 87602 18967): this is located on the proposed scheme and extends to approximately 200m south of the A12. It was first identified on the 1881 map as a brickfield, also shown as brick works on the 1897 map and as ‘old gravel pits’ with ponds on the 1954-1987 maps. The A12 was constructed on the northern part of the site on the 1969-1970 map including the Brick Kiln farmhouses immediately south of the road. The ponds are currently present. Great Eastern Railway - Kelvedon branch line crossing (TL 87329 18665) chainage 47800: this railway line crosses the route of the A12, shown on the 1924, 1938 and 1955 maps but was shown as dismantled on the 1971 map.

Junction 24 to 25
Existing A12: A Roman road was shown on the proposed scheme on the earliest map from 1875-1876 with no significant changes up to 1923. The road was expanded on the 1958 map. Further expansion including the junctions was shown on the 1954-1989 maps. No significant changes are shown on successive maps to present day.
Junction 25 to end of the proposed scheme
Existing A12: As for junction 24 to 25. Further expansion was shown on successive map in 1963 including construction of the A12/A120 Marks Tey roundabout. Marks Tey rail depot - dormant mineral extraction site (TL 92270 24170). This site is located on the proposed scheme. The London Road landfill is located immediately south of this site. There was no evidence of any pit on this site on the historical maps from 1875 to present.

3.7 Soil surveys

3.7.1 Soil surveys are detailed studies of the characteristics of soil within a given area. They contribute to soil classification in accordance with the Agricultural Land Classification (ALC) of England and Wales classification system, provide predictions of soil behaviours and identify land of uses.

3.7.2 The ALC of England and Wales is a system to grade the quality of land for agricultural use according to the extent by which physical or chemical characteristics impose long-term limitations. The system classifies land into five grades where ‘Grade 1’ is ‘excellent quality’. The east of England ALC map shows the soils along the route to be; Grade 2 – Very Good and Grade 3 – Good to moderate. An area around Witham is shown as ‘Land predominately in urban use’. An ALC survey has been undertaken for the proposed scheme and findings have been reported in Chapter 10: Geology and soils, of the Environmental Statement [TR010060/APP/6.1].

3.8 Previous ground investigations

3.8.1 Historical ground investigation data obtained from the Highways Agency Geotechnical Data Management System (HA GDMS) and the British Geological Survey (BGS) Geology of Britain Viewer and GeoIndex Onshore Database were reviewed. The available data are not relevant to this assessment and have not been included in this report.

3.9 Consultations with statutory bodies and agencies

3.9.1 Through consultation of the Environmental Scoping Report (Highways England, 2020), Natural England, Historical England and local authority archaeological advisers were made aware of ground investigation works (and potential borrow pit sites). Meetings with Natural England and heritage consultees were held on 3 September 2020 and 14 October 2020, respectively. The Environment Agency was made aware of the locations of boreholes for groundwater monitoring through the ongoing drainage design and water environment assessment consultation.

3.9.2 Stakeholders including the Environment Agency and local authority environmental health officers have been consulted on the Environmental Scoping Report (Highways England, 2020). A summary is provided in the Environmental Scoping Opinion (Planning Inspectorate, 2021) (TR010060-000009-CHLM).

3.9.3 The Environment Agency has been consulted to provide information on historical landfills located along the proposed scheme at Witham near junction 21 and London Road to the south-east of junction 25. The Environment Agency confirmed the nature of waste received in each of the landfills and the dates of operation. The information received from the EA is summarised in Table 3.8. They advised that a site investigation should be considered to determine the ground conditions in locations where the proposed scheme would encroach on historical landfill sites.

3.10 Land contamination

3.10.1 A preliminary risk assessment was undertaken as part of PSSRs for the proposed scheme route development options to identify the main potential land contamination constraints. Potentially significant sources of land contamination identified within 250m of the proposed scheme were assessed using a source-pathway-receptor risk assessment to identify the main constraints. The GI has been undertaken to investigate the preliminary source-pathway-receptor linkages identified in the PSSR of the proposed scheme including borrow pits through soil, groundwater and ground gas sampling. The land contamination findings of the GI are discussed in Section 5.5 of this report and Section 6 (for borrow pits), the updated CSM following the GI is presented in Table 5.20 and Table 6.4 for the borrow pits. Risks and mitigation measures are summarised in the risk register in Section 5.6 of this report.

3.10.2 The potential sources of contamination identified on and within 250m of the proposed scheme are summarised in Table 3.7 below. The land contamination constraints plans are included in Figure 10.1 of the Environmental Statement [TR010060/APP/6.2], which includes the main land contamination constraints identified and the exceedances of the screening criteria for soil, soil leachate and groundwater identified during the GI.

Table 3.7 Potential sources of land contamination within 250m of the proposed scheme

Potential sources of land contamination	Description
Historical landfills	Six historical landfill sites are located within 250m of the proposed scheme. Refer to Section 3.11 of this report for more information.
Industrial areas	Nine industrial areas were identified along the proposed scheme which could be potential sources of made ground and contaminated soils.

Potential sources of land contamination	Description
Petrol stations and garages	Six active and two historical petrol stations have been identified along the proposed scheme with four active garages and one historical garage. All locations could be potential sources of hydrocarbons and fuel vapours.
Made Ground (Infilled mineral extraction pits)	10 historical extraction pits have been infilled with materials that could be a potential source of contamination.
Made Ground (Existing roadway, dismantled railways, railway sidings)	Two dismantled railways cross the proposed scheme, as well as an existing railway siding at Marks Tey. The contamination potential of Made Ground associated with the existing A12 construction is also unknown.

3.11 Historical landfills

3.11.1 Based on the information received from the Environment Agency in December 2020, there are several historical landfill sites within 250m of the proposed scheme located within design section 2 to 3. Four are located at Witham between junction 21 and 22, two of these are phased landfills located in one area within the Whetmead LNR (referred to in this report as Whetmead LNR Witham landfill), the third is located within the Witham sewage works (Blackwater Lane landfill) and the fourth within the Witham industrial area (Perry Way landfill).

3.11.2 Two are located to the south-east of junction 25 – London Road landfill and Foundry Lane landfill, Copford.

3.11.3 The locations of the landfills are summarised in Table 3.8 below and shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].

3.11.4 The information on waste types received, date of operation and landfill operator summarised below were received from the Environment Agency in December 2020 as part of the consultation process.

Table 3.8 Historical Landfills within 250m of the proposed scheme

Landfill	National grid reference (approximate)	Waste type received	Operation date including operator	Distance from proposed scheme	Current use
East of Railway Line	TL 83050 13850	Industrial, commercial and household	1964 -1974 Witham Urban District Council	Adjacent and possibly underlying the A12	Whetmead LNR and A12 highway
Perry Road		Industrial, commercial and liquids/sludge	1977 – 1990 Witham Urban District Council		
Blackwater Lane	TL 82757 13831	Household and hazardous	1958 - 1964	Adjacent and possibly underlying the A12	Partially undeveloped, sewage treatment works and A12 highway
Perry Way (Witham) Also named Maldon Road in the envirocheck report	TL 82751 14283	Industrial, commercial and liquids/sludge	1963 - 1964 Witham Urban District Council	170m east	Warehouse in Witham Industrial Estate
London Road (near junction 25)	TL 92373 24035	Land infilled with material from Stanway by-pass construction	1960 - 1972	Adjacent and possibly underlying the A12	Field with some pavement used as a car boot sale site and A12 Highway
Foundry Lane	TL 92914 24150	Inert, household and industrial	1958 - 1980	150m south	Residential properties

3.11.1 It should be noted that the proposed scheme would encroach on the boundaries of some of these landfills (Whetmead LNR Witham landfill, Blackwater Lane landfill and London Road landfill). A ground investigation of the London Road landfill has been undertaken as part of the Phase 3 GI to assess the nature and contamination status of the material within the landfill. A risk assessment has been undertaken based on the GI findings.

3.11.2 The Whetmead LNR Witham landfill GI was completed on 21st January 2022.

3.12 Unexploded ordnance (UXO) / unexploded bombs (UXB)

3.12.1 Information on UXO for the proposed scheme was obtained from the following sources:

- Zetica Regional Unexploded Bomb (UXB) Risk map for Essex.(http://www.zetica.com/uxb_downloads.htm)
- Zetica Ltd, A12 Junction 19 to Junction 25, Pre-Desk Study Assessment, 2 February 2017
- Zetica Ltd, A12 Junction 24 to Junction 25, Pre-Desk Study Assessment, 17 July 2018
- Zetica UXO Ltd, A12 Chelmsford, J19 to J21 and Borrow Pits. UXO Desk Study & Risk Assessment, Document No. P7265-17-R1, Revision B, 24 January 2018
- UXO Desk Study & Risk Assessment report, Document Ref. P9142-19-R1, dated 23 December 2019

3.12.2 The information from these reports is summarised in this report.

3.12.3 The UXO report indicates the proposed scheme is predominately low risk, with one area of moderate risk within the Order Limits at Potts Green south of junction 25. However, the area of moderate risk is indicated to be approximately >95m east of the proposed scheme's earthworks and is therefore unlikely to be disturbed during the works. See Plates 3.1 and 3.2 for the UXO risk maps for the proposed scheme.

Plate 3.1 Plan of UXO risk – design section 1 and the start of design section 2

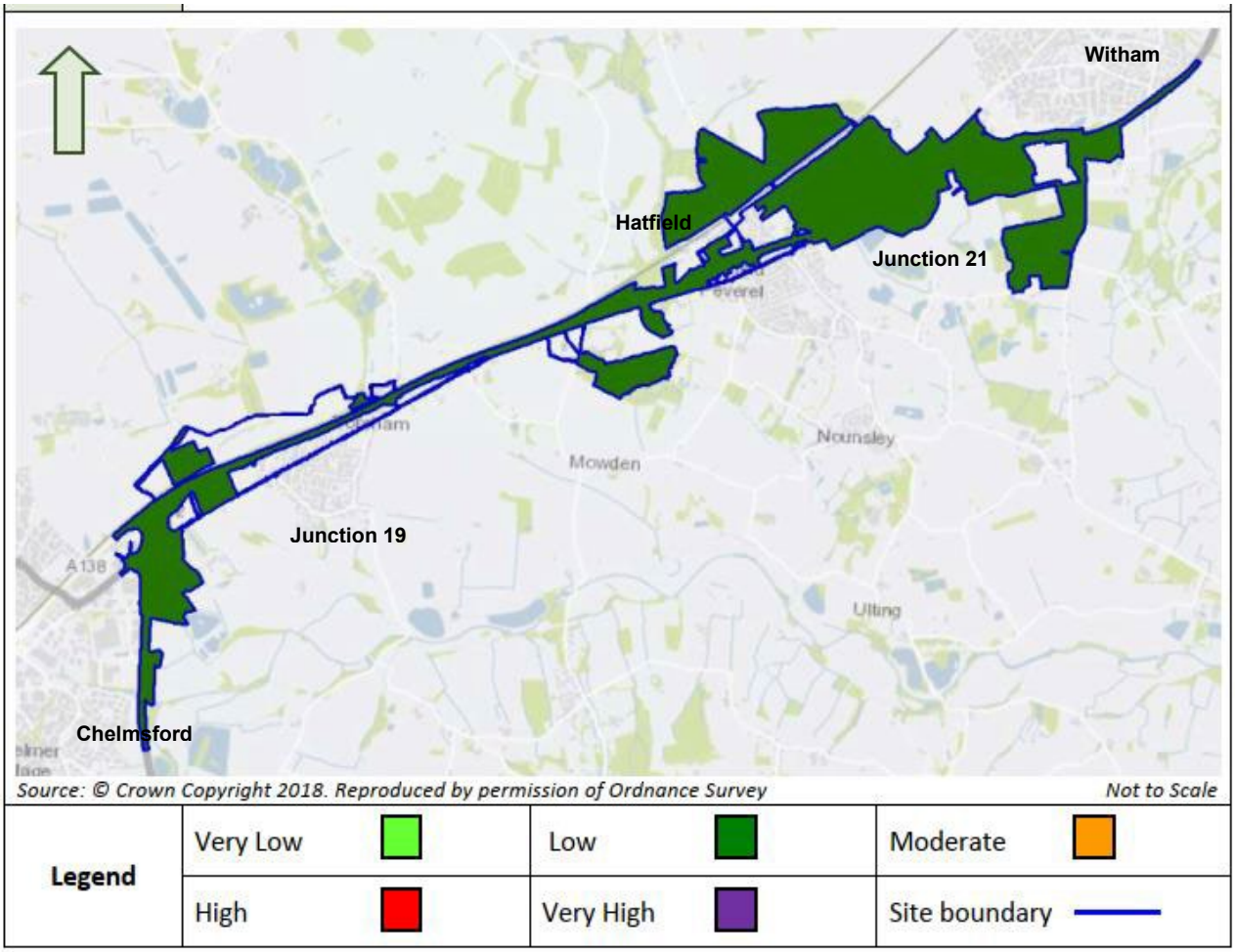
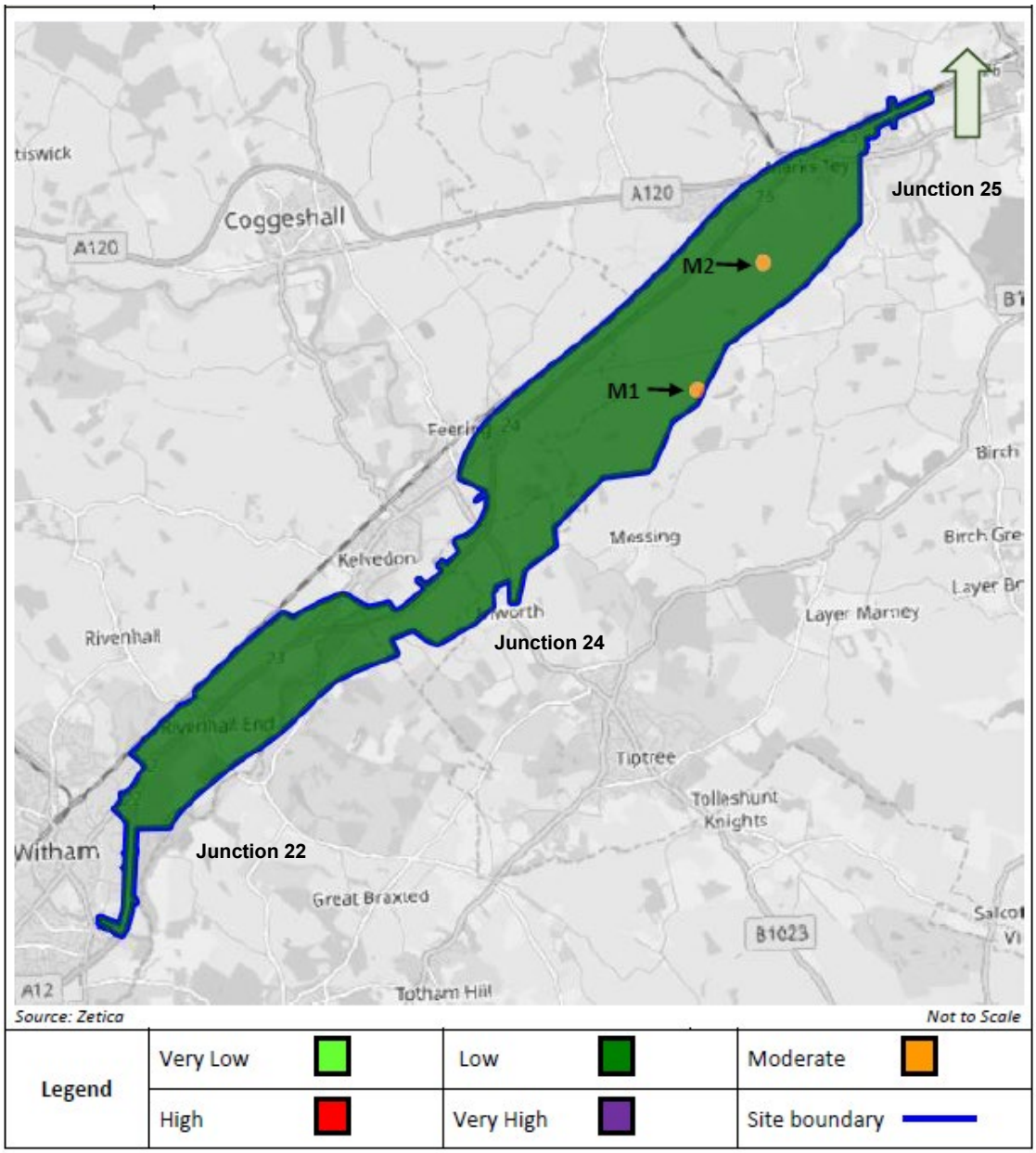


Plate 3.2 Plan of UXO risk – design section 2 and design section 3



3.13 Hydrology

The hydrology of the proposed scheme is discussed in detail in Chapter 14: Road drainage and the water environment, of the Environmental Statement [TR010060/APP/6.1]. Surface water features which may be affected by any land contamination exposed and mobilised during the scheme development works are covered in this report and include surface water crossings.

3.13.1 The proposed scheme crosses a number of rivers and brooks which are summarised in Table 3.9 below. There are also a number of surface water features within 250m of the proposed scheme including ditches, ponds, reservoirs and rivers; these are detailed in Chapter 14: Road drainage and the water environment, of the Environmental Statement [TR010060/APP/6.1]. The

rivers, brooks and surface water features are illustrated on Plates 3.3, 3.4 and 3.5.

Table 3.9 Surface water crossings

Surface water crossings	Approximate chainage		River quality			Flood zone
	Online sections	Offline sections	GQA grade	Year of assessment	WFD assessment (2015)	
Junction 19 to 20						
Boreham Brook	11+600	No offline section	Not provided	Not provided	Moderate	Zone 2 and 3
Junction 20 to 21						
River Ter	15+510	No offline section	A (Very Good	2000	Moderate	Zone 2 and 3
Junction 21 to 22						
River Brain	21+150	No offline section	C (Fairly Good)	2000	Not assessed	Zone 2 and 3
Junction 22 to 23						
Rivenhall Brook	24+600	24+590	Not provided	Not provided	Moderate	Zone 2 and 3
Junction 23 to 24						
River Blackwater	26+400	No offline section	B (Good)	2000	Good	Zone 2 and 3
Domsey Brook	31+900	No offline section	Not provided	Not provided	Good	Zone 2 and 3
Junction 24 to 25						
Domsey Brook	39+355	51550	Not provided	Not provided	Good	Zone 2 and 3
Junction 25 to end of the proposed scheme						
No surface water crossings present						

Plate 3.3 River crossings and surface water features located in design section 1 of the proposed scheme

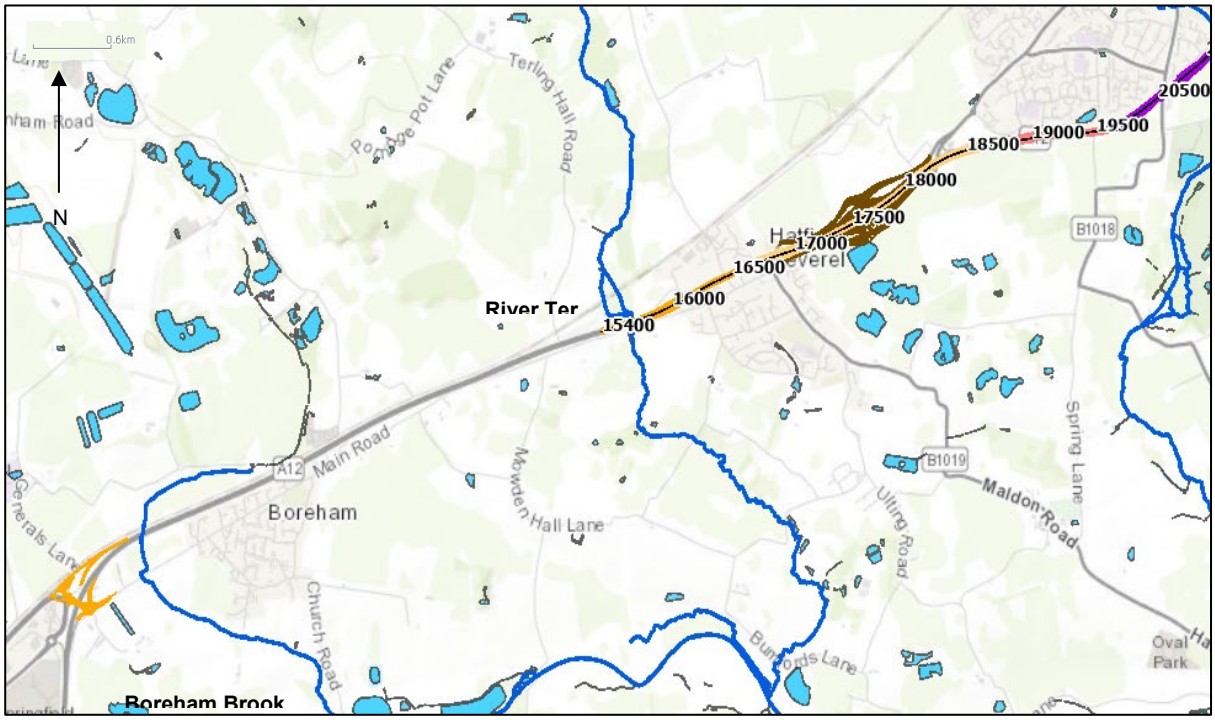


Plate 3.4 River crossing and surface water features located in design section 2 of the proposed scheme

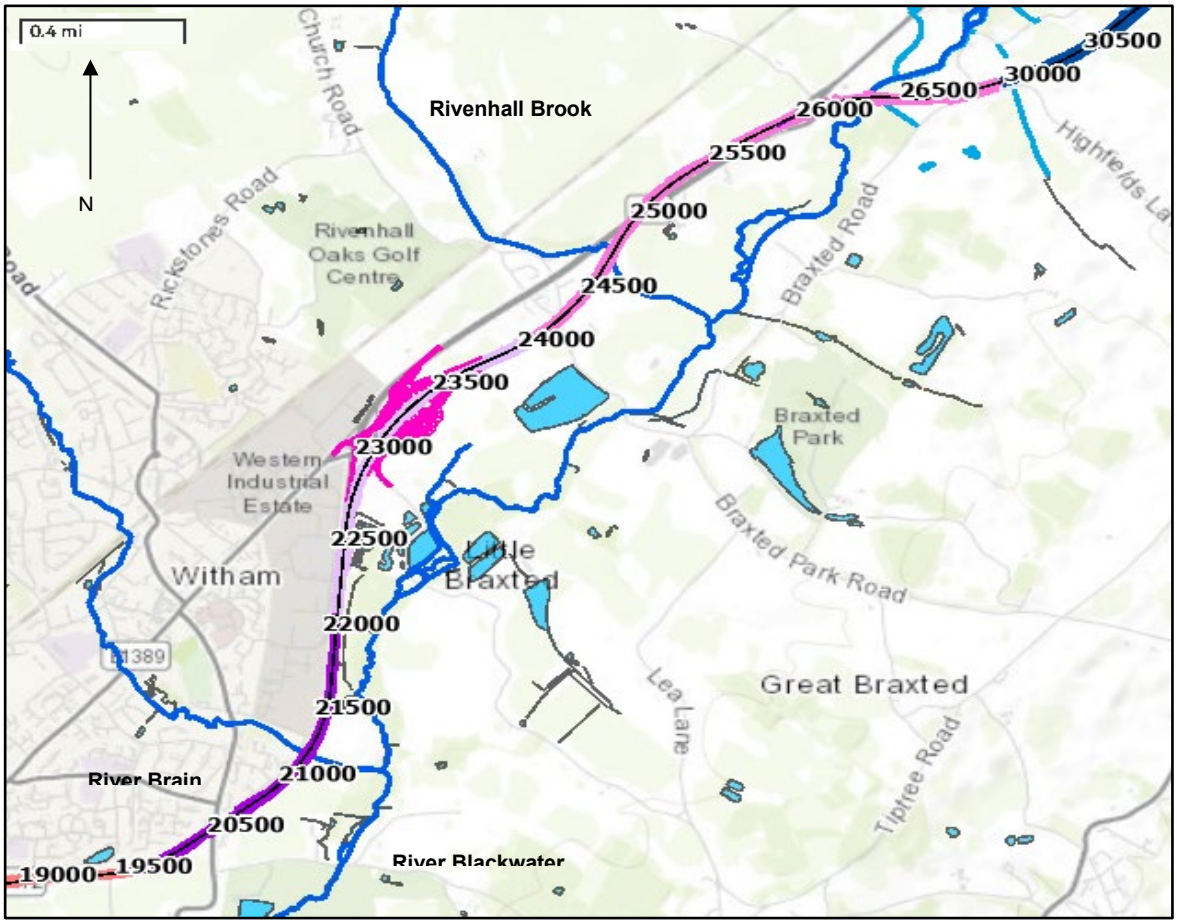
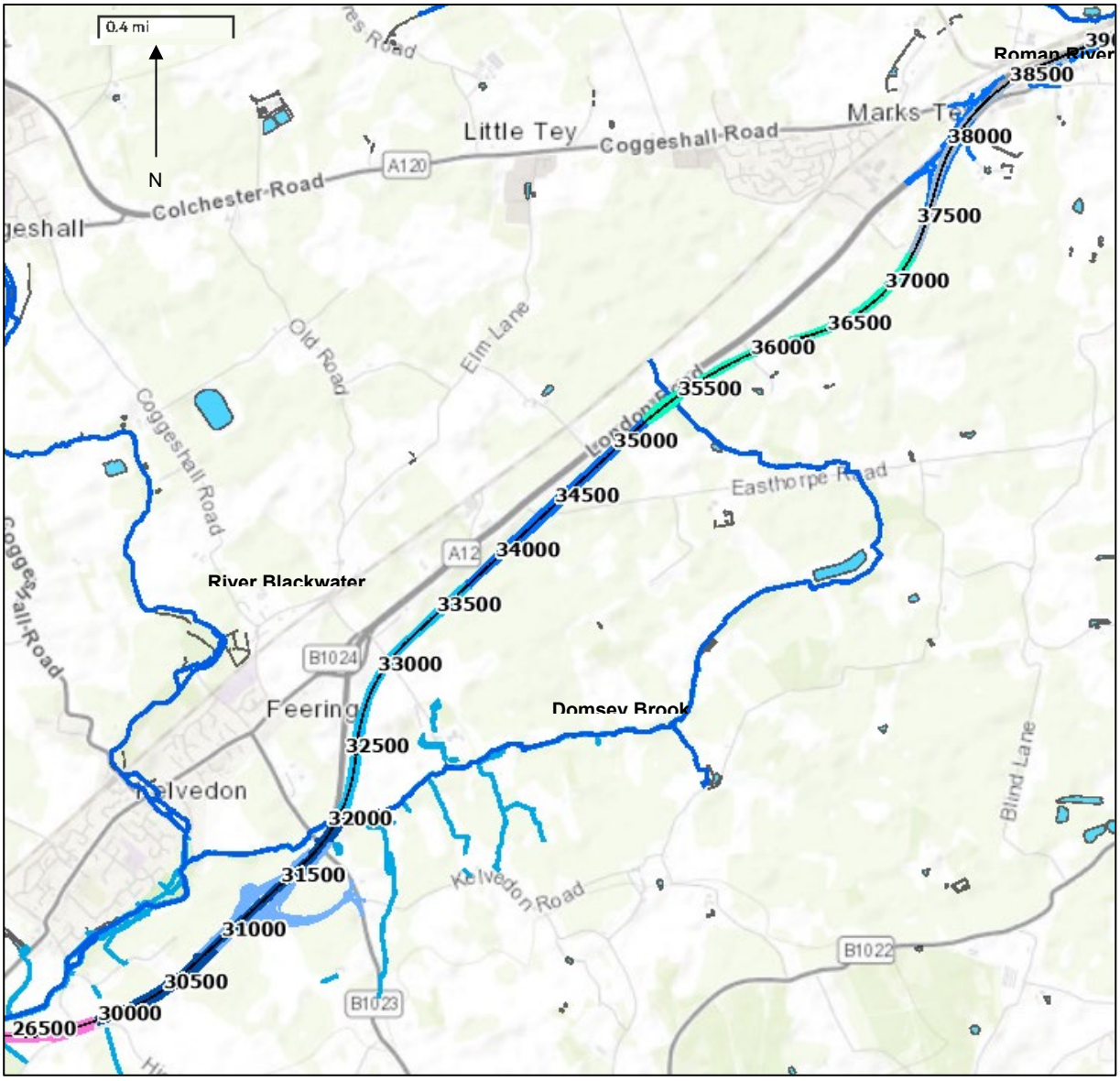


Plate 3.5 River crossing and surface water features located in design section 3 of the proposed scheme



Surface water abstractions

3.13.2 Surface water abstractions identified close to the proposed scheme are shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2]. The potential impacts of the proposed scheme on controlled waters including surface water abstractions are detailed in Section 5.5 of this report.

Surface water flow

3.13.3 The following Table 3.10 summarises the anticipated surface water flow direction based on the local topography in relation to the alignment. The topographic information used for this analysis is publicly available Environment Agency LiDAR DTM survey data.

Table 3.10 Anticipated surface water flow derived from topographic data

Location	Topographic detail
Design section 1	
CH 09+500 to 10+150	Surface water would flow from west to east down slope towards the A12 alignment as it is located on the western side of the Chelmer Valley.
CH 10+150 to 11+500 (Junction 19)	Junction 19 is located near the peak of the side wall of the Chelmer Valley where the existing A12 mainline is cut into a small gap in the valley walls aligned SSW to NNE and curving round to the WSW to ENE. Surface water would flow from the north east and north west towards the south, running down the existing and proposed alignment cutting and against the north of the two proposed bridge abutments/embankments. Surface water would also flow from the east and west towards the proposed junction embankment to the west and into the proposed junction cuttings to the east. This continues to the east of junction 19, with the angle of flows changing to north and south. As the route heads up Boreham hill the groundwater flow would move from east to west, flowing towards the proposed embankments either side of the mainline.
CH 11+500 to 15+400	Past Boreham the route lies on high ground where the majority of the surface water in the area would flow to the north and south away from the alignment, however as the alignment is located within a cutting some surface water may still flow into the cutting.
CH 15+400 to 17+000	Surface water would flow from the north and predominantly from the south into the A12 cutting and along the A12 to the west.
CH 17+000 to 18+200	Past Hatfield Peverel the alignment passes along the southern side of Hatfield Hill with surface water flow predominantly from the north moving towards low ground to the east. This would result in surface water flowing from the north towards the proposed alignment which is in shallow cutting.
CH 18+200 to 19+200	The alignment passes south of Witham perpendicular to the line of slope, therefore surface water flow into the embankment supporting the A12 should be minimal
CH 19+200 to 19+500	As the route curves to the north around Witham Hill the surface water would flow from the north west towards the A12 flowing into the cutting face to the proposed embankment northern toe
Design section 2	
CH 19+500 to 20+600	The route continues to the north around Witham Hill the surface water would flow from the north west towards the A12 northern embankment side.
CH 20+600 to Junction 22	As the alignment moves north into the Blackwater Valley the surface water would continue to flow from the valley sides in the west towards the A12 embankment toe. The majority of the land to the west is paved industrial areas therefore the flow may be significant due to minimal infiltration of rainfall into the ground.

Location	Topographic detail
Junction 22	Junction 22 is located at the base of the western valley side, therefore surface water would flow from the north west towards the junction.
CH 23+700 to 26+000	Surface water would flow from the north west towards the western side of the A12 alignment and into the valley base. The majority of this surface run off would be towards the northern A12 mainline embankment toe.
CH 26+000 to 26+500	As the alignment crosses the River Blackwater Valley surface water flow should be directed into the river through the existing culverts rather than towards the A12.
CH 26+500 to 26+900	The alignment heads to the north east along the eastern side of the River Blackwater Valley. Surface water would flow down the valley slope from south east to north west towards the A12 embankment northern toe.
Design section 3	
CH 30+000 to 32+000	The alignment continues to the north east along the eastern side of the River Blackwater Valley. Surface water would flow down the valley slope from south east to north west towards the A12 embankment.
CH 32+000 to 33+000	The alignment crosses a relatively flat area and perpendicular to minor slopes where present and therefore surface water runoff would be minimal.
CH 33+000 to 35+000	Surface water would flow from the north west downslope towards the A12 alignment.

Flood risk

3.13.4 Flood risk is detailed in Chapter 14: Road drainage and the water environment, of the Environmental Statement [TR010060/APP/6.1] and the Flood Risk Assessment (Appendix 14.5 of the Environmental Statement [TR010060/APP/6.3]).

3.14 Hydrogeology

3.14.1 The mapped superficial deposits (Defra, 2020) are classified mainly as secondary A and secondary undifferentiated aquifers with discrete areas of secondary B aquifer between junctions 19 (Boreham) and 20b (Hatfield Peverel South) and of unproductive strata in the vicinity of Rivenhall End. To the north of CH 33+000 the superficial deposits are shown as a secondary (undifferentiated) aquifer associated with the Lowestoft Formation deposits which dominate in the design section 3 area of the proposed scheme (see Table 3.11).

Table 3.11 Strata aquifer designations – design sections 1, 2 and 3

Superficial deposits	**Aquifer designation**
Alluvium	Secondary A
River Terrace Deposits	Secondary A
Head Deposits	Secondary undifferentiated
Glaciolacustrine Deposits	Unproductive strata
Lowestoft Formation (formerly known as Boulder Clay)	Secondary undifferentiated
Glaciofluvial deposits	Secondary A
Brickearth	Secondary B
Bedrock	**Aquifer designation**
London Clay Formation	Unproductive strata
Thanet Formation (mainly at depth and does not occur at the surface in the study area). One small area is mapped as subcropping in the east of Witham at CH 22+950	Secondary A
Chalk Group (Upper and Middle Chalk) (at depth and does not occur at the surface in the study area)	Secondary A
Lambeth Group (at depth and does not occur at the surface for most of the study area). One small area of Thanet Formation and Lambeth Group (undifferentiated) is mapped as subcropping to the west of Kelvedon at CH 26+500.	Principal

3.14.2 The groundwater vulnerability map (Defra, 2020) shows that the majority of the proposed scheme lies on secondary superficial aquifers with medium-low vulnerability. Small areas of low and medium vulnerability are present to the west of junction 21. Small areas of medium-high vulnerability are also present associated with the Thanet Formation and Lambeth Group undifferentiated and Thanet Formation sub-crop areas in the vicinity of Witham and Kelvedon. A small area of low-medium vulnerability is also present to the south-east of Kelvedon. The London Clay is expected to act as an aquiclude, minimising impact on the materials below.

3.14.3 A high-level assessment of groundwater levels reported in borehole logs shown on the BGS GeoIndex website (BGS, 2020) indicated that groundwater levels in the superficial deposits are likely to be encountered at varying depths, and frequently the borehole logs show groundwater is not encountered during drilling. However, the logs do also show that groundwater can be encountered at relatively shallow depth, within 1.0m or 2.0m of the ground surface. The impact of this potential for shallow groundwater is discussed further in Section 5 of this report.

3.14.4 The vast majority of the design section 1 and 2 areas of the proposed scheme overlie the Essex Gravels Water Framework Directive (WFD) groundwater water body (GB40503G000400) (Environment Agency, 2020c). This currently

has ‘poor’ overall status due to its poor chemical quality and an objective of achieving ‘good’ status by 2027. To the north of CH 32+500 the design section 3 area of the proposed scheme does not lie within a designated WFD groundwater body except for the extreme northern end which is also in the Essex Gravels Water Framework Directive groundwater water body. In the area of design section 3 groundwater currently has ‘poor’ overall status due to its poor chemical quality and an objective of achieving ‘good’ status by 2027.

3.14.5 A small number of licensed groundwater abstractions have been identified within the design section 1 area of the proposed scheme (Landmark Information Group, 2016). These abstractions are associated with agricultural abstractions for spray irrigation. Groundwater abstractions identified within the vicinity of the design section 2 area of the proposed scheme are largely associated with agricultural abstractions for spray irrigation, although an industrial abstraction is licensed in Witham at Station Maltings.

3.14.6 It is currently uncertain whether these abstractions are from the shallow superficial deposits or from the confined Chalk. However, based on the borehole logs available on the BGS GeoIndex site (BGS, 2020), for some of the boreholes it is more likely that the groundwater is abstracted from the superficial deposits (most likely to be sand and gravel deposits which form the secondary A superficial aquifers). The Anglian Water abstraction, however, is thought to be from the confined Chalk aquifer.

3.14.7 The groundwater Source Protection Zone (SPZ) map (Defra, 2020) shows that the design section 1 and 2 areas of the proposed scheme does not lie within a source protection zone. The groundwater source protection zone map shows that the design section 3 area of the proposed scheme to the north of CH 31+050 lies within a source protection zone (SPZ3). This SPZ3 is associated with the Chalk abstractions to the north of the proposed scheme and due to the protection offered by the overlying London Clay there would not be any impacts on the abstractions for which the SPZ3 is defined. A 50m radius inner source protection zone (SPZ1) is also defined for a public water supply borehole at Inworth Road which is within approximately 50m of the design section 3 area of the proposed scheme. This abstraction is believed to be from the Chalk and the overlying London Clay deposits would provide protection to the groundwater abstraction. Liaison with the Environment Agency has confirmed that these locations were dropped from their licencing in 2016 (email 13 May 2022) and the Environment Agency would be removing the SPZ associated with these wells from their database.

3.14.8 Groundwater abstractions of less than 20m^3/day do not require a licence. The location of unlicensed groundwater abstractions may be recorded by the local authority and this information has been obtained, although records may not be complete. The closest is shown to be a few metres from junction 22. The potential impact of the proposed scheme on groundwater abstractions is discussed in Section 5 of this report.

3.14.9 Groundwater Dependent Terrestrial Ecosystems (GWDTEs) are wetlands which critically depend on groundwater flows or chemistry. An initial assessment of the locally designated ecological sites has been undertaken as indicated in Table 3.12 to determine the potential groundwater dependency of the Local Wildlife

Sites (LWSs) and Local Nature Reserves (LNRs) and sites defined as coastal and floodplain grazing marsh priority habitat.

Table 3.12 Potential Local Wildlife Site GWDTEs within 500m of the proposed scheme and an initial assessment of their groundwater dependency

Ecologically designated Site name	Site reference	Initial assessment of potential groundwater dependency
Design section 1		
River Chelmer LWS	Ch 109	Medium
The Grove LWS	Ch 107	Medium
Boreham Road Gravel Pits	Ch 113	High
Coastal and floodplain grazing marsh priority habitat	Adjacent Chelmsford Water Recycling Centre	Medium
Design section 2		
Riverview Meadows LWS	Bra174	High
Whet Mead LNR	Bra183	Medium
Kelvedon Hall Wood LWS	Ma52	Low
Brockwell Meadows	Bra229	Medium
Design section 3		
Brockwell Meadows	Bra229	Medium

3.14.10 Groundwater abstractions identified close to the proposed scheme which may be potentially impacted by any land contamination exposed during the proposed scheme development are shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2], Chapter 10: Geology and soils of the Environmental Statement [TR010060/APP/6.1] and discussed in Section 5.5 of this report.

3.14.11 The potential impact of the proposed scheme and associated works on the local hydrogeological regime are also covered in the following documents:

- Chapter 14: Road drainage and the water environment, of the Environmental Statement [TR010060/APP/6.1]
- Flood Risk Assessment (FRA) (Appendix 14.5 of the Environmental Statement [TR010060/APP/6.3])

4 Field and laboratory studies

4.1 Introduction

4.1.1 The GI comprised of geotechnical surveys, contaminated land surveys and other ancillary surveys not detailed in this report including topographic, ecological and pavement surveys.

4.1.2 **Phase 1 GI** – this was completed between November 2019 to June 2020 encompassing design section 1 of the mainline works including junctions 19, 20 and 21, associated attenuation pond and all the 11 borrow pits. A final AGS dataset was received on 5 of May 2021 and final factual reports were received between 26 April and 18 May 2021, including all GI and laboratory testing information.

4.1.3 **Phase 2 GI** - Covers design section 2 of the mainline works and junctions 22 and 23. Phase 2 GIs have been partially undertaken, being split at the request of Costain into two sub-packages referred to as: Phase 2a and Phase 2b.

- Phase 2a GIs were carried out between mid-May 2020 and October 2020, targeting predominately mainline geotechnical locations. A final AGS dataset was received on 5 of May 2021 and final factual reports were received on 29 April 2021 including all GI and laboratory testing information.

- The Phase 2b GI scope has been rationalised by Jacobs following receipt of Phase 2a GI data. The Phase 2b GI has three primary objectives:

    1. To enable the understanding of the regional groundwater levels and seasonal fluctuations, and potential for impacts on groundwater receptors. These primarily related to monitoring points between the proposed road and potential Groundwater Dependent Terrestrial Ecosystems (GWDTEs). Construction of the road may lead to water quality or flow/level impacts in the GWDTEs. Groundwater level data are required to determine groundwater flow directions and flow rates in relation to GWDTEs and impacts have been assessed as part of the Environmental Impact Assessment (EIA).

    2. To develop an understanding of the potential ground conditions which may have an impact on the preliminary drainage design proposals and the land-take requirements for the DCO boundary e.g., the feasibility of using Sustainable drainage systems/infiltration techniques will impact the drainage design proposals and their associated land-take requirements. In addition, any constraints identified from the Phase 2b GIs e.g., potential shallow groundwater levels, unsuitable geology and/or land contamination will, if necessary, enable the development of alternative drainage design proposals during the preliminary design stage.

    3. To determine the extent and nature of land contamination in areas where the proposed scheme is located near historical landfill sites at Witham between J21 and 22, and other potentially contaminated areas including a large industrial estate at Witham.

- Based on recent discussions with Costain, it is now understood that the Phase 2b GI package will be incorporated into the gap analysis and supplementary GI design for the scheme. The GI scoped as part of the gap analysis would be undertaken as part of Stage 5 - Detailed Design works.

4.1.4 **Phase 3 GI** - Covers design section 3 of the mainline works and junctions 24 and 25. Fieldwork was completed between November 2020 and February 2021. Although the final AGS dataset and GI factual report for the Phase 3 GI have not been received at the time of writing this report, all the relevant geo-environmental data have been provided and used in this assessment.

4.2 Walkover survey

4.2.1 A full reconnaissance of the proposed scheme was undertaken in 2017 to assess the potential constraints to the proposed developments. This was required to visually assess the potential constraints identified from the desk study review of existing information.

4.2.2 As part of the Early Works Orders relating to the Intrusive Survey Works Contract, limited site walk overs were carried out in agreement with the current landowners by representatives of the Principal Contractor, the GI contractor and Ecological Clerk of Works (ECoW) prior to all exploratory holes being located.

4.3 Ground investigations

4.3.1 The purpose of the ground investigation was to provide ground investigation data to support PCF Stage 3 - Preliminary Design of the proposed scheme including the mainline widening, junction expansion, bridge widening, earthwork modification, borrow pits, culverts and attenuation ponds. The scope and design of the GI was primarily to obtain information on; ground and groundwater conditions, investigate potential land contamination sources identified, asses the geotechnical properties of the ground, obtain information on possible mineral resources and undertake preliminary waste assessment to determine the possibilities for re-use of excavated materials.

4.3.2 Ground Investigation data was provided in AGS 4.1 format and has been used as the primary source of information in which to analyse the results of the ground investigations.

4.4 Description of fieldwork

4.4.1 Field works undertaken as part of the Phase 1, 2 and 3 GI are summarised in Table 4.1 below:

Table 4.1 Exploratory holes summary

Exploratory hole type	Abbreviation	Total	Groundwater monitoring installations
Phase 1			
Windowless Sampler	WS or WLS	79	32
Cable Percussive with Rotary Follow on[(1)]	CP+RC	30	30
Cable Percussive	CP	98	98
Inspection Pit	IP	28	-
Trial Pit	TP	217	-
Phase 2			
Windowless Sampler	WS	12	9
Cable Percussive with Rotary Follow on[(1)]	CP+RC	34	38
Cable Percussive	CP	15	15
Inspection Pit	IP	15	-
Trial Pit	TP	4	-
Phase 3			
Windowless Sampler	WS or WLS	46	22
Cable Percussive with Rotary Follow on[(1)]	CP+RC	21	21
Cable Percussive	CP	57	48
Inspection Pit	IP	4	-
Trial Pit	TP	85	-
Rotary Open	RO	2	2
Lightweight Deflectometer	LWD	5	-

Notes

[(1)] Cable percussion and rotary drilling follow on boreholes were either completed as 1 hole or 2 holes with the rotary borehole open holed to termination depth of the associated cable percussion location

Groundwater monitoring installations and sampling

4.4.2 Groundwater monitoring was undertaken between January 2020 and April 2021 and at the time of writing this report was still ongoing. Table 4.2 below summarises the available groundwater monitoring data.

Table 4.2 Summary of groundwater monitoring readings

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
GI Phase 1					
BH+RC1102	2.00	10.20	Glaciofluvial Deposits	1.15 – 1.41	22.75 – 22.49
BH+RC1104	1.50	5.00	Lowestoft Formation	0.34 – 3.60	25.06 – 21.80
BH+RC1106	0.75	3.00	Glaciofluvial Deposits	2.54 – 3.00 (Dry)	36.21
BH+RC1106	4.00	9.00	Glaciofluvial Deposits	4.60 – 7.99	39.60 – 36.21
BH+RC1107	1.00	8.50	Glaciofluvial Deposits	3.76	40.54
BH+RC1108	0.90	7.10	Glaciofluvial Deposits	3.55 – 3.66	36.35 – 36.24
BH+RC1109	1.00	2.20	Made Ground	Dry	Dry
BH+RC1109	3.00	7.50	Glaciofluvial Deposits	4.50 – 5.60	37.00 – 35.90
BH+RC1110	3.00	10.20	Lowestoft Formation	Dry	Dry
BH+RC1111	3.00	12.00	Lowestoft Formation	9.53 – 10.08	34.97 – 34.42
BH+RC1112	5.00	12.00	Glaciofluvial Deposits	5.40 – 9.29	38.7 – 34.81
BH+RC1113	1.00	10.20	Lowestoft Formation	3.40 – 3.79	38.7 – 38.31
BH+RC1114	4.00	10.00	Glaciofluvial Deposits	4.79 – 5.00	33.91 – 33.70
BH+RC1115	1.50	9.00	Lowestoft Formation	3.18 – 5.85	33.12 – 30.45
BH+RC1117	1.20	7.00	Made Ground / River Terraces Deposits	1.93 – 4.11	34.37 – 32.19
BH+RC1160a	4.00	9.00	Glaciofluvial Deposits	5.40 – 5.64	18.10 – 17.86
BH+RC1161	1.20	4.00	Made Ground	3.95 – 4.00 (Dry)	19.75 – 19.70 (Dry)
BH+RC1161	5.40	10.00	Glaciofluvial Deposits	5.33 – 5.62	18.37 – 18.08
BH+RC1162	1.50	20.00	Lowestoft Formation	1.48	34.82
BH+RC1163	0.75	5.00	Glaciofluvial Deposits	2.62 – 4.86	37.88 – 35.64
BH+RC1164a	0.75	3.00	Made Ground	2.45 – 3.85	20.45 – 19.05
BH+RC1164a	3.50	7.50	Made Ground / Lowestoft Formation	3.91 – 6.14	18.99 – 16.76
BH+RC1166	0.75	3.00	Made Ground	1.40 – 2.13	16.90 – 14.17
BH+RC1166	3.50	7.00	River Terrace Deposits	4.02 – 4.52	12.28 – 11.78

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH+RC1177A	0.50	6.75	Glaciofluvial Deposits	3.48 – 3.82	22.92 – 22.58
BH+RC1178	0.90	4.10	Made Ground	2.80 – 4.10 (Dry)	30.50 – 29.20
BH+RC1178	5.40	10.60	Lowestoft Formation	8.80 – 9.11	24.50 – 24.19
BH+RC1181	1.00	5.00	Made Ground / Head / River Terrace Deposits	4.72 – 5.10*	13.78 – 13.40
BH+RC1181	5.50	9.00	River Terrace Deposits / Glaciofluvial Deposits	4.83 – 4.14	13.67 – 13.36
BH1001	1.00	2.00	Made Ground / Lowestoft Formation	0.43	22.87
BH1001	2.25	3.25	Lowestoft Formation	2.55	20.75
BH1014	5.00	10.00	River Terrace Deposits	6.48 – 6.71	14.12 – 13.89
BH1101	1.00	4.00	Made Ground / Glaciofluvial Deposits	0.90 – 1.31	20.20 – 19.79
BH1103	1.00	6.00	Head / Lowestoft Formation	2.71 – 4.17	30.89 – 29.43
BH1159	1.00	6.00	Head / Glaciofluvial Deposits	4.20 – 5.26	25.30 – 24.24
BH1180	1.00	6.00	Made Ground / Lowestoft Formation	4.65 – 6.00 (Dry)	17.45 – 16.10
WS1402	1.00	4.00	Made Ground / Glaciofluvial Deposits	2.01 – 2.03	24.79 – 24.77
WS1403	0.80	4.50	Glaciofluvial Deposits	2.47 – 4.13	24.33 – 24.67
WS1420	1.00	3.00	Made Ground	Dry	21.70 (Dry)
WS1422	1.00	4.00	London Clay Formation	1.79 – 4.00 (Dry)	34.61 – 32.40 (Dry)
WS1428	1.00	6.00	Lowestoft Formation / Glaciofluvial Deposits	Dry	43.4 (Dry)
WS1430	1.80	5.20	Lowestoft Formation	2.22 – 2.33	24.79 – 24.77
WS1431	0.80	6.45	Lowestoft Formation	0.55 – 3.34	43.75 – 40.96
WS1432	0.90	6.00	Head	5.45 – 6.61(1)	39.05 – 37.89
WS1434	1.00	6.00	Lowestoft Formation	1.82	18.78
WS1435b	0.80	6.00	Head / River Terrace Deposits	2.88 – 3.30	14.72 – 14.30

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
WS1436	1.50	5.50	Made Ground / River Terrace Deposits	5.10 – 5.11	17.90 – 17.89
WS1437b	1.00	3.00	River Terrace Deposits	Dry	17.10 (Dry)
WS1499	0.80	2.50	Glaciofluvial Deposits	No data	No data
WS1506	0.50	4.00	Head	2.75 – 4.00 (Dry)	30.85 – 29.60 (Dry)
WS1507	1.00	4.00	London Clay Formation	Dry	
WS1509	2.50	7.70	Lowestoft Formation	2.63 – 3.93	37.17 – 35.87
WS1510	1.80	7.00	Lowestoft Formation	4.71 – 5.42	37.09 – 38.38
WS1511	2.65	5.00	Lowestoft Formation	1.86 – 3.96	29.64 – 27.54
WS1512	1.00	4.00	Lowestoft Formation	3.35 – 3.85	41.25 – 40.75
WS1513	1.00	3.50	Lowestoft Formation	1.25 – 1.82	25.25 – 24.68
WS1514	0.80	5.00	River Terrace Deposits	0.95 – 1.44	17.35 – 16.86
WS1517	0.50	2.00	Head / River Terrace Deposits	0.45 – 1.72	18.85 – 17.58
WS1519	0.80	5.00	Head / Glaciofluvial Deposits	1.11 – 2.19	25.69 – 24.61
WS1520	0.80	5.00	Alluvium / Head	2.71 – 3.55	19.19 – 18.35
WS1521	0.80	5.00	Alluvium / Head	4.12 – 4.44	18.48 – 18.16
WS1522	0.80	5.00	Head	2.20 – 2.90	20.40 – 17.80
WS1523	1.00	5.00	Lowestoft Formation	1.66 – 3.90	19.04 – 16.80
WS1524	0.80	4.55	Lowestoft Formation	4.55 – 4.55 (Dry)	36.95
WS1525	0.80	4.00	Head / Glaciofluvial Deposits	1.86 – 4.00 (Dry)	39.64 – 37.50
WS1526	0.80	5.00	Head / River Terrace Deposits	1.32 – 2.23	15.78 – 13.07
WS1527	0.80	4.00	River Terrace Deposits	1.87 – 2.46	13.43 – 12.84
GI Phase 2					
BH+RC2201A	0.50	5.00	Made Ground	2.73 – 3.73	14.17 – 13.17
BH+RC2201A	6.00	10.00	Alluvium / River Terrace Deposits	2.78 – 5.00	14.02 – 11.90

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH+RC2203	10.00	26.00	Lowestoft Formation	No data	No data
BH+RC2204	2.00	3.00	River Terrace Deposits	No data	No data
BH+RC2204	4.00	6.00	River Terrace Deposits	No data	No data
BH+RC2205A	1.00	5.00	River Terrace Deposits	No data	No data
BH+RC2205A	6.00	14.50	Lowestoft Formation / Glaciofluvial Deposits	No data	No data
BH+RC2220	1.00	8.00	River Terrace Deposits	4.42	12.58
BH+RC2220	9.00	30.00	Lowestoft Formation	3.93 – 16.00	13.07 – 1.00
BH+RC2222	5.50	11.00	Head / River Terrace Deposits	4.12	15.48
BH+RC2222	11.50	20.50	Lowestoft Formation	4.02	15.58
BH+RC2225	2.00	4.00	River Terrace Deposits	4.00 (Dry)	13.00
BH+RC2225	5.00	20.50	River Terrace Deposits / Lowestoft Formation	6.35	10.65
BH+RC2260	3.00	30.00	River Terrace Deposits / Lowestoft Formation	1.88 – 3.02	15.22 – 14.08
BH+RC2261	7.50	16.00	River Terrace Deposits / Lowestoft Formation	16.00 (Dry)	5.90 (Dry)
BH+RC2261	18.00	24.00	Lowestoft Formation	3.65 – 5.75	18.25 – 16.15
BH+RC2262	1.00	30.45	River Terrace Deposits / Lowestoft Formation	5.88 – 8.80	16.02 – 13.10
BH+RC2264	1.00	5.00	Alluvium / River Terrace Deposits / Interglacial Silt and Clay Deposits	0.73 – 1.01	19.17 – 18.89
BH+RC2264	6.00	25.00	Interglacial Silt and Clay Deposits / Lowestoft Formation	0.67 – 1.21	19.23 – 18.69
BH+RC2266	1.00	6.00	Head Deposits / River Terrace Deposits / Lowestoft Formation	5.00	19.50
BH+RC2266	7.00	37.00	Lowestoft Formation	2.35	22.15
BH+RC2267	7.50	16.00	Glaciofluvial Deposits / Lowestoft Formation	2.66 – 3.30	19.44 – 18.80

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH+RC2267	18.00	24.00	Lowestoft Formation	2.59 – 3.22	19.51 – 18.88
BH+RC2269	5.00	9.00	Lowestoft Formation	No data	No data
BH+RC2269	9.50	13.30	Glaciofluvial Deposits / Lowestoft Formation	No data	No data
BH+RC2270	2.90	18.00	River Terrace Deposits / Lowestoft Formation	4.21 – 5.05	24.79 – 23.95
BH+RC2271	1.00	5.00	River Terrace Deposits / Lowestoft Formation	5.00 (Dry)	21.00 (Dry)
BH+RC2271	10.00	20.50	Lowestoft Formation	3.95 – 10.13	22.05 – 15.87
BH+RC2272A	2.00	4.00	River Terrace Deposits	2.18 – 3.25	18.92 – 17.58
BH+RC2272A	5.00	6.50	River Terrace Deposits	2.30 – 3.99	18.80 – 17.11
BH+RC2273	1.50	4.00	Alluvium / River Terrace Deposits	0.80 – 1.20	18.10 – 17.70
BH+RC2273	7.00	20.50	River Terrace Deposits / Interglacial Silt and Clay Deposits / Glaciofluvial Deposits / Lowestoft Formation	0.78 – 1.31	18.12 – 17.59
BH+RC2274A	2.00	12.50	Made Ground / River Terrace Deposits / Lowestoft Formation	9.30 – 9.97	20.30 – 19.63
BH+RC2606	1.00	6.00	River Terrace Deposits	5.32 – 6.00 (Dry)	24.28 – 23.60 (Dry)
BH+RC2606	7.00	16.00	Interglacial Silt and Clay Deposits / Lowestoft Formation	5.30 – 5.98	24.30 – 23.62
BH+RC2620	1.00	5.00	Made Ground / River Terrace Deposits	5.00 (Dry)	16.70 (Dry)
BH+RC2620	6.00	9.00	River Terrace Deposits / Lowestoft Formation	6.07 - 9.00 (Dry)	15.63 – 13.20 (Dry)
BH+RC2640	4.00	6.50	River Terrace Deposits	No data	No data
BH+RC2676	2.00	5.70	River Terrace Deposits	3.59 – 3.66	12.81 – 12.74
BH2240	1.00	10.50	Head Deposits / River Terrace Deposits	4.33	12.57
BH2240	11.00	20.00	Lowestoft Formation	4.40	12.50

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH2263	2.00	4.00	River Terrace Deposits	4.00 (Dry)	18.10 (Dry)
BH2603	2.50	10.45	River Terrace Deposits / Lowestoft Formation	No data	No data
BH2604	1.00	4.50	Interglacial Lacustrine Deposits / River Terrace Deposits / Lowestoft Formation	No data	No data
BH2607	2.00	4.00	River Terrace Deposits	No data	No data
BH2607	5.00	30.50	River Terrace Deposits / Lowestoft Formation	6.35	18.70
BH2609	1.00	10.00	Head Deposits / River Terrace Deposits / Lowestoft Formation	2.87	13.63
BH2609	11.50	20.45	Lowestoft Formation	2.62	13.88
BH2623	4.00	6.50	River Terrace Deposits / Lowestoft Formation	4.05 – 4.11	14.15 – 14.09
BH2623	7.50	20.45	Lowestoft Formation	4.01 – 4.08	14.19 – 14.12
BH2625	7.00	10.50	River Terrace Deposits / Glaciofluvial Deposits	3.91 – 5.55	18.79 – 17.15
BH2645	2.00	4.00	River Terrace Deposits	4.00 (Dry)	12.40 (Dry)
BH2645	4.50	10.00	River Terrace Deposits / Lowestoft Formation	4.46 – 4.55	12.40 – 11.85
BH2649	1.50	8.00	River Terrace Deposits	5.67	10.93
BH2649	9.00	14.45	Lowestoft Formation	5.43	11.17
BH2664	1.50	18.70	Head Deposits / River Terrace Deposits / Lowestoft Formation / Glaciofluvial Deposits	0.15 – 0.55	16.25 – 15.85
BH2667	1.50	10.00	Head Deposits / Lowestoft Formation	4.00 – 4.46	23.10 – 22.64
BH2674	3.00	6.50	River Terrace Deposits	3.71 – 4.60	13.09 – 12.20
WS2408	1.80	4.50	Lowestoft Formation	No data	No data
WS2412B	2.00	4.00	River Terrace Deposits / Lowestoft Formation	No data	No data

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
WS2446	1.30	3.50	Head Deposits / River Terrace Deposits	3.50 (Dry)	14.40 (Dry)
WS2446	4.00	7.40	Lowestoft Formation	6.60 – 7.40 (Dry)	11.30 – 10.90 (Dry)
WS2462	2.00	4.20	River Terrace Deposits / Lowestoft Formation	0.80 – 2.31	27.90 – 26.39
WS2465B	0.50	4.50	Head Deposits	No data	No data
WS2465B	6.00	10.45	Interglacial Silt and Clay Deposits	No data	No data
GI Phase 3					
BH+RC3201	8.00	18.00	Glaciofluvial Deposits	8.63 – 8.78	27.67 – 27.52
BH+RC3202	5.50	19.00	Glaciofluvial Deposits	11.68 – 11.82	24.62 – 24.48
BH+RC3203	3.50	12.00	Glaciofluvial Deposits	8.42 – 8.62	25.43 – 25.23
BH+RC3204	8.50	16.00	Glaciofluvial Deposits	7.87 – 8.09	25.23 – 25.04
BH+RC3205	10.00	22.00	Glaciofluvial Deposits	0.40 – 0.48	25.25 – 25.17
BH+RC3206	1.00	4.00	Made Ground Road Embankment	Dry	Dry
BH+RC3206	5.00	9.00	River Terrace Deposits	5.80 – 6.98	23.95 – 22.77
BH+RC3207	2.50	6.50	River Terrace Deposits	4.33 – 4.60	26.67 – 29.40
BH+RC3207	37.50	40.20	Glaciofluvial Deposits	6.38 – 6.56	27.62 – 27.44
BH+RC3208	2.00	5.50	Head Deposits	3.01 – 3.33	30.16 – 29.82
BH+RC3208	37.00	40.00	Glaciofluvial Deposits	5.37 – 5.54	27.78 – 27.61
BH+RC3209	7.00	13.50	Glaciofluvial Deposits	4.15 – 4.22	27.50 – 27.43
BH+RC3210	6.50	12.70	Glaciofluvial Deposits	2.93 – 2.99	27.37 – 27.31
BH+RC3213	2.00	17.50	Lowestoft Formation	0.40 – 4.40	39.05 – 35.05
BH+RC3215	7.00	15.00	Glaciofluvial Deposits	9.65 – 9.74	32.60 – 32.51
BH+RC3216	6.00	14.50	Glaciofluvial Deposits	9.08 – 9.17	32.62 – 32.53
BH+RC3217	7.00	16.00	Kesgrave Catchment Subgroup	No data	No data
BH+RC3218	4.00	12.50	Kesgrave Catchment Subgroup	6.41 – 6.51	30.19 – 30.09

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH3002	1.00	10.00	Glaciofluvial Deposits / London Clay Formation	1.14 – 1.39	24.41 – 24.16
BH3003	2.00	4.20	London Clay Formation	1.34 – 1.51	24.06 – 23.89
BH3004	1.00	5.00	River Terrace Deposits	2.92 – 3.18	24.06 – 23.89
BH3005	4.00	6.00	Glaciofluvial Deposits	3.37 – 3.58	24.08 – 23.87
BH3006	3.50	10.00	Glaciofluvial Deposits	4.56 – 4.71	24.49 – 24.34
BH3007	5.00	7.00	Lowestoft Formation	5.31 – 5.69	30.64 – 30.26
BH3007	8.50	10.00	Glaciofluvial Deposits	Dry	Dry
BH3008	2.70	4.70	Glaciofluvial Deposits	Dry	Dry
BH3008	6.00	10.00	Glaciofluvial Deposits	5.69 – 5.93	24.91 – 24.67
BH3009	5.50	7.50	Lowestoft Formation	0.96 – 1.39	31.29 – 30.86
BH3011	1.00	2.00	Made Ground	No data	No data
BH3011	3.00	10.00	River Terrace Deposits / Lowestoft Formation	7.85	28.00
BH3012	1.00	5.00	Made Ground / Lowestoft Formation	No data	No data
BH3012	5.50	14.50	Interglacial Silt and Clay Deposits / Lowestoft Formation	5.21	29.89
BH3013	1.00	15.00	Lowestoft Formation	0.60 – 1.00	25.30 – 24.90
BH3015	2.50	8.50	River Terrace Deposits	4.26 – 4.43	26.59 – 26.42
BH3017	1.50	10.00	Lowestoft Formation	2.26 – 3.12	32.14 – 32.28
BH3021	5.00	14.70	Glaciofluvial Deposits	No data	No data
BH3022	2.00	14.00	Lowestoft Formation	1.21 – 1.23	26.99 – 26.97
BH3023	2.00	10.00	Glaciofluvial Deposits	3.19 – 3.25	27.46 – 27.40
BH3025	6.50	10.00	Glaciofluvial Deposits	6.49 – 6.76	27.31 – 27.04
BH3027	2.10	10.60	Glaciofluvial Deposits	3.38 – 3.55	27.67 – 27.50
BH3030	3.50	5.50	Glaciofluvial Deposits	3.76 – 4.00	34.84 – 34.60
BH3031	8.00	10.00	Glaciofluvial Deposits	6.05 – 6.26	34.75 – 34.54

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH3032	1.50	9.60	Lowestoft Formation / Glaciofluvial Deposits	2.05 – 2.55	38.00 – 37.50
BH3033	8.50	13.00	Glaciofluvial Deposits	1.24 – 1.78	34.11 – 33.57
BH3034	3.50	5.00	Alluvium	0.59 – 4.70	32.16 – 28.05
BH3034	18.50	20.00	Glaciofluvial Deposits	Borehole flooded	Borehole flooded
BH3035	9.00	13.00	Glaciofluvial Deposits	0.37 – 0.49	32.93 – 32.81
BH3035	16.50	20.00	Glaciofluvial Deposits	0.35 – 0.54	32.95 – 32.76
BH3036	2.50	4.50	Lowestoft Formation	3.51 – 3.62	33.04 – 32.93
BH3036	5.50	10.00	Glaciofluvial Deposits	3.53 – 3.65	33.02 – 32.90
BH3037	1.50	9.00	Lowestoft Formation	1.05 – 1.40	35.30 – 34.95
BH3038	1.40	3.40	Lowestoft Formation	1.11 – 2.42	36.84 – 35.53
BH3038	4.00	10.00	Lowestoft Formation / Glaciofluvial Deposits	3.41 – 4.04	34.54 – 33.91
BH3039	1.30	3.30	Lowestoft Formation	No data	No data
BH3041	7.00	10.00	Glaciofluvial Deposits	9.95 – 10.05	32.25 – 32.15
BH3043	5.00	10.00	Glaciofluvial Deposits	3.88 – 9.96	30.52 – 30.44
BH3045	0.60	1.40	Made Ground	1.30	39.95
BH3045	5.00	10.00	Kesgrave Catchment Subgroup	Dry	Dry
BH3046	6.00	10.00	Glaciofluvial Deposits	9.87	30.38
BH3049A	4.00	8.00	Kesgrave Catchment Subgroup	1.28 – 6.32	33.87 – 28.83
BH3050	1.50	7.00	Kesgrave Catchment Subgroup	4.95 – 5.05	28.45 – 28.35
BH3051	0.50	1.50	Made Ground	1.05 – 1.38	31.50 – 31.17
BH3051	2.00	10.00	Kesgrave Catchment Subgroup	4.36 – 4.45	28.19 – 28.10
BH3052	2.00	10.00	Made Ground / Kesgrave Catchment Subgroup	2.79 – 2.89	28.01 – 27.91

Location ID	Response zone (m bgl)		Geological stratum	Water level range (m bgl)	Water level range (m AOD)
	Top	Base			
BH3053	2.00	10.00	River Terrace Deposits / Kesgrave Catchment Subgroup	1.14 – 1.37	28.01 – 27.78
BH3054	1.50	6.00	Alluvium / Glacial Fluvial Deposits	3.34	28.65
WS3402G	1.00	5.00	Lowestoft Formation	1.20 – 1.51	20.75 – 20.44
WS3403	1.00	3.00	Alluvium	1.28 – 1.34	24.07 – 24.01
WS3405	1.00	5.00	Lowestoft Formation	0.58 – 3.95	29.27 – 25.90
WS3406	1.00	5.00	Lowestoft Formation	1.75 – 2.15	32.75 – 32.35
WS3408	0.80	5.00	River Terrace Deposits / Lowestoft Formation	1.22 – 3.40	24.18 – 22.00
WS3409	1.00	5.00	Lowestoft Formation	0.90 – 3.04	23.30 – 21.16
WS3413	1.00	5.00	Lowestoft Formation	1.12 – 1.23	30.03 – 29.92
WS3416	1.00	5.00	Lowestoft Formation	0.85 – 1.09	26.65 – 26.41
WS3417	0.90	4.30	Glaciofluvial Deposits	3.36 – 3.58	27.69 – 27.47
WS3418	1.00	4.00	Glaciofluvial Deposits	Dry	Dry
WS3419	1.00	5.00	Lowestoft Formation	1.11 – 1.24	38.84 – 38.71
WS3422	1.00	5.00	Lowestoft Formation	1.04 – 1.19	40.11 – 39.96
WS3424	1.00	4.00	Lowestoft Formation	3.92 – 4.45	35.28 – 34.75
WS3425	0.50	5.00	Lowestoft Formation	0.89 – 1.20	39.76 – 39.45
WS3426	1.00	5.00	Lowestoft Formation	1.90 – 3.03	34.00 – 32.87
WS3427	1.00	5.00	Lowestoft Formation	0.82 – 1.26	35.53 – 35.09
WS3428	4.00	5.00	Glaciofluvial Deposits	2.98 – 3.64	34.47 – 33.81
WS3430	1.00	5.00	Lowestoft Formation	1.11 – 1.38	37.69 – 37.42
WS3431	1.00	5.00	Lowestoft Formation	No data	No data
WS3432	1.00	5.00	Lowestoft Formation	1.12 – 1.58	39.58 – 39.12
WS3435	1.50	2.70	Lowestoft Formation	Dry	Dry
WS3436	1.00	5.00	Interglacial Deposits	3.20 – 3.62	28.45 – 28.03

Notes

(1) Reported water level is deeper than the response zone targeted.

Groundwater quality assessment

4.4.3 A groundwater quality assessment was undertaken to assess the chemical quality of the groundwater underlying the proposed scheme and to provide baseline data which will be used during later stages of the scheme development to assess the impact, if any, of the proposed scheme on controlled waters during and after construction works. Prior to sampling, the wells were purged and groundwater parameters (pH, temperature, Dissolved Oxygen (DO), Electrical Conductivity (EC), reduction/oxidation potential) were measured at regular intervals until they had generally stabilised.

4.4.4 The laboratory analysis undertaken for groundwater samples is summarised in Table 4.5 and the results are discussed in Section 4.5 of this report.

Ground gas monitoring

4.4.5 Ground gas monitoring was undertaken in selected standpipe locations shown in Table 4.3 below. The boreholes were monitored using a Gas Data GFM 435 gas monitor and MiniRae 2000 PID (photo ionisation detector) for volatile organic compounds (VOC) monitoring. Measurements of flow, atmospheric pressure, concentrations of methane, carbon dioxide, oxygen, hydrogen sulphide, carbon monoxide, VOC and of groundwater levels were taken during each round. The results of the gas monitoring are presented in Table 4.3 and are discussed in Section 4.4 of this report.

Table 4.3 Summary of ground gas monitoring standpipes

Location ID	Response zone (m bgl)		Geological formation
	Top	Base	
GI Phase 1			
BH1001	1.00	2.00	Made Ground / Lowestoft Formation
BH+RC1104	1.50	5.00	Lowestoft Formation
BH+RC1106	0.75	3.00	Glaciofluvial Deposits
BH+RC1109	1.00	2.20	Made Ground
BH+RC1114	4.00	10.0	Glaciofluvial Deposits
BH+RC1166	0.75	3.00	Made Ground
BH+RC1177A	0.50	6.75	Glaciofluvial Deposits
BH+RC1178	5.40	10.60	Lowestoft Formation
BH+RC1181	1.00	5.00	Made Ground / Head / River Terrace Deposits
WS1422	1.00	4.00	London Clay Formation
WS1432	0.90	6.00	Head

Location ID	Response zone (m bgl)		Geological formation
	Top	Base	
WS1437b	1.00	3.00	River Terrace Deposits
WS1523	1.00	5.00	Lowestoft Formation
GI Phase 2			
BH+RC2201A	0.50	5.00	Made Ground
BH+RC2201A	6.00	10.00	River Terrace Deposits / London Clay Formation
BH+RC2676	2.00	5.70	River Terrace Deposits / London Clay Formation
BH2625	7.00	10.50	River Terrace Deposits / Glaciofluvial Deposits
BH2674	3.00	6.50	River Terrace Deposits / London Clay Formation
GI Phase 3			
BH3025	6.50	10.00	Glaciofluvial Deposits
BH3049A	4.00	8.00	Kesgrave Catchment Subgroup
BH3050	1.50	7.00	Kesgrave Catchment Subgroup
BH3051	0.50	1.50	Made Ground
BH3051	2.00	10.00	Kesgrave Catchment Subgroup
BH3052	2.00	10.00	Made Ground / Kesgrave Catchment Subgroup
BH3053	2.00	10.00	Glaciofluvial Deposits / Kesgrave Catchment Subgroup
BH+RC3206	5.00	9.00	River Terrace Deposits
BH+RC3218	4.00	12.50	Kesgrave Catchment Subgroup
WS3436	1.00	5.00	Interglacial Deposits

4.5 Laboratory analysis

Geo-environmental analysis

4.5.1 Chemical analysis of geo-environmental samples was undertaken by i2 Analytical in accordance with their UKAS and MCERTS accredited test methods.

Soil

4.5.2 A total of 378 soil samples (including borrow pits) were collected from the proposed scheme and analysed in the laboratory for various suites to determine the chemical concentrations of the determinands analysed in soil.

4.5.3 Some of the samples were analysed for soil leachability testing and Landfill Waste Acceptance Criteria (WAC) testing.

4.5.4 Table 4.4 provides a summary of all the laboratory analysis undertaken for soil samples.

Table 4.4 Summary of soil laboratory analysis

Laboratory analysis suites	Total No.
Suite E1 Metals; semi-metalloids; inorganics; Total Petroleum Hydrocarbons (TPH) including Benzene, Toluene, Ethylbenzene and Xylene (BTEX); Polycyclic Aromatic Hydrocarbons (PAH); asbestos screen and quantification.	378
Suite E2 Volatile and Semi-Volatile Organic Compounds (VOC and SVOC).	17
Suite E3 Polychlorinated Biphenyls (PCB).	10
Suite E4 Soil Leachate Suite: BS12457 2:1: metals and semi-metalloids.	148
Suite H Waste Acceptance Criteria (WAC): Testing using BS EN12457 10:1 (single stage leaching process at a liquid: solid ratio of 10:1).	57

Groundwater

4.5.5 A total of 166 groundwater samples were collected from the areas affected by the proposed scheme (including the borrow pits) and scheduled mainly for suite FI. Limited samples were scheduled for expanded suites F2 where organic contaminants are likely to be present. These are summarised in Table 4.5.

Table 4.5 Summary of groundwater laboratory analysis

Laboratory analysis suites	Total No.
Suite F1 Metals; semi-metalloids; inorganics; Total Petroleum Hydrocarbons (TPH) including Benzene, Toluene, Ethylbenzene and Xylene (BTEX); Polycyclic Aromatic Hydrocarbons (PAH).	166
Suite F2 Volatile and Semi-Volatile Organic Compounds (VOC and SVOC).	Limited samples

4.6 Factual data reports

4.6.1 Some adjustments are anticipated following final review by Jacobs and liaison with GEL and Costain. These are primarily associated with:

- Discrepancies of a small number of exploratory hole levels against site specific LiDAR DTM
- x, y, coordinate discrepancy with 2 No. exploratory holes
- GEOL_GEO2 code errors

4.6.2 All of the above issues have been temporarily corrected by Jacobs to enable progression of this report. Individual factual pdf reports were produced by GEL by section and carriageway direction, as summarised below.

Table 4.6 Summary of factual reports

Section	GEL report date	Date received	Report status	Comments
Borrow pit A	February 2021	February 2021	Final	The reports have been provided as final but further revisions are anticipated following errors identified in the accompanying AGS data.
Borrow pit B	February 2021	February 2021		
Borrow pit C	February 2021	February 2021		
Borrow pit D	February 2021	February 2021		
Borrow pit E	February 2021	February 2021		
Borrow pit F	February 2021	February 2021		
Borrow pit G	February 2021	February 2021		
Borrow pit H	February 2021	February 2021		
Borrow pit I	February 2021	February 2021		
Borrow pit J	February 2021	February 2021		
Borrow pit L	February 2021	February 2021		
Eastbound carriageway	February 2021	February 2021		
Eastbound offline	February 2021	February 2021		
Westbound carriageway	February 2021	February 2021		
Westbound offline	February 2021	February 2021		

5 Ground summary

5.1 Introduction

5.1.1 This section provides the ground conditions encountered during the Phases 1 to 3 GIs.

5.2 Limitations and assumptions

5.2.1 The following limitations and assumptions apply:

5.2.2 This section provides the ground conditions encountered during the Phases 1 to 3 GIs. The Phase 1 (including borrow pits) and Phase 2 GIs were designed and undertaken at an earlier stage in the design process and as such there are local discrepancies between GI locations and proposed design element locations. A gap analysis is currently being undertaken at the time of writing this report based on subsequent design fixes to enable supplementary GI to be designed. This will be followed by a further site- specific GI which would be undertaken as part of the Stage 5 detailed design works.

5.2.3 The Phase 2 GI was limited to the mainline only.

5.3 Geology

5.3.1 Tables 5.1 and 5.2 below summarise the ground conditions encountered during the Phases 1 to 3 GIs.

Table 5.1 Superficial geological summary

Strata	Top of strata (m bgl)			Base of strata (m bgl) [1]			Top of strata (m AOD)			Base of strata (m AOD) [1]			Thickness (m) [1]		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Made Ground-Road Embankment	0.00	1.20	0.38	0.80	7.50	3.47	15.65	33.50	21.41	12.15	32.70	18.32	0.80	7.00	3.10
Reworked Natural Deposits	0.00	0.00	0.00	0.05	1.60	0.39	12.85	50.60	28.30	12.35	50.00	27.91	0.05	1.60	0.39
Made Ground	0.00	0.00	0.00	0.15	5.50	0.79	14.25	45.35	28.96	13.95	44.85	28.17	0.15	5.50	0.79
Alluvium	0.00	4.70	0.71	0.95	6.20	3.01	12.15	31.25	20.45	10.65	30.70	18.14	0.55	4.75	2.31
Peat	1.30	3.20	2.10	2.20	3.50	2.97	13.05	15.00	14.17	12.75	13.60	13.30	0.30	1.40	0.87
Brickearth	0.20	0.40	0.30	0.80	1.10	0.93	32.55	33.15	32.88	31.75	32.55	32.25	0.50	0.80	0.63
Head Deposits	0.05	3.70	0.63	0.50	6.00	1.57	14.70	50.00	26.84	14.05	48.90	25.89	0.15	2.30	0.94
Interglacial Silt and Clay	0.30	3.80	1.63	0.85	5.60	3.45	17.20	37.70	26.76	16.10	33.80	24.94	0.55	3.90	1.82
River Terrace Deposits	0.30	6.20	1.51	1.60	8.90	4.27	10.65	29.05	16.32	8.50	28.55	13.56	0.50	5.60	2.76

Strata	Top of strata (m bgl)			Base of strata (m bgl) [1]			Top of strata (m AOD)			Base of strata (m AOD) [1]			Thickness (m) [1]		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Glaciolacustrine Deposits	0.00	5.75	2.16	2.40	9.20	4.15	18.75	36.70	30.21	15.30	35.70	28.22	0.85	3.45	1.99
Lowestoft Formation	0.15	4.90	0.80	0.70	36.00	6.67	19.90	48.90	34.14	-11.35	40.60	28.27	0.40	31.45	5.87
Glaciofluvial Deposits	0.30	28.50	3.61	1.20	34.50	7.59	43.75	-4.00	28.27	-10.00	36.40	24.29	0.35	13.00	3.98
Kesgrave Catchment Subgroup	0.20	6.70	3.54	5.80	16.40	9.96	30.40	33.40	32.07	23.10	27.60	25.65	3.10	9.70	6.42

Notes

[1] Only boreholes that penetrated the superficial deposits into the London Clay Formation have been used in the assessment.

Table 5.2 Solid geology summary

Strata	Top of strata (m bgl)			Base of strata (m bgl)			Top of strata (m AOD)			Base of strata (m AOD) [1]			Thickness (m)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
London Clay Formation	0.30	36.00	5.64	Not proven			40.60	-11.50	22.86	Not proven			Not proven	>38.40	Not proven

5.3.2 The following section describes the ground conditions taken from the PSSRs, supplemented by the findings of the proposed scheme specific GI.

Made ground road embankment

5.3.3 Cohesive example of this material is typically described as firm to very stiff sandy gravelly silty clay an contains fragments of chalk, flint, brick and organic material.

5.3.4 Granular examples of this material are typically described as loose to dense sandy silty gravel of chalk, flint and brick.

Reworked natural deposits

5.3.5 At the time of writing this report, Topsoil had not been differentiated on the logs, or described in accordance with BS 5930. All material likely to be Topsoil where there is no anthropogenic material present, has been assigned as Reworked Natural Deposits. This material is typically described soft to stiff sandy gravelly silty clay an contains fragments of chalk, flint and brick.

Made ground

5.3.6 The Made Ground not consisting of reworked natural material or embankment fill is typically described as soft to stiff sandy gravelly silty clay and commonly contains fragments of chalk, flint, brick and organic material.

Alluvium

5.3.7 The BGS Lexicon of Named Rock Units typically describes Alluvium as normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present. The BGS Memoir describes Alluvium as soft, pale brown silty clay with traces of organic matter.

5.3.8 Material interpreted as Alluvium has been encountered in the exploratory holes and is highly variable but typically described as; very soft to stiff brown / orangish brown organic slightly sandy, slightly gravelly silty clay with occasional peat. The material appears to have generally been removed from beneath the existing alignment earthworks.

River terrace deposits

5.3.9 The BGS Lexicon of Named Rock Units typically describes River Terrace Deposits as sand and gravel, locally with lenses of silt, clay or peat.

5.3.10 Material interpreted as River Terrace Deposits has been encountered in the exploratory holes and is typically described as brown or orangish brown, silty sand and gravel with occasional flint cobbles, or slightly gravelly fine to coarse sand. The gravel is commonly described as fine to course, rounded to sub-rounded, of flint and quartzite.

5.3.11 Cohesive examples of this material have also been identified as 0.1 to 1.0m thick lenses within the granular deposits and are commonly described as laminated clayey fine sandy silt and can contain small amounts of organic material.

Head deposits

5.3.12 The BGS Lexicon of Named Rock Units typically describes Head as a polymict deposit (sourced from different materials) comprising gravel, sand and clay depending on upslope source and distance from source. Head often consist of poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hillwash and soil creep. Generally, the Head deposits comprise sand and gravel, locally with lenses of silt, clay or peat and organic material. The BGS Memoir describes Head as being derived from different parent materials and is therefore comprised of silty sands, silty clays and chalk free orange-brown stony clay.

5.3.13 Material interpreted as Head Deposits has been encountered in the exploratory holes. It is highly variable but typically described as soft to stiff orangish brown or brown, sandy, silty clay or clayey silt with occasional fine to medium gravel, or slightly clayey sand gravel. The generally lower strength, position of the deposits, i.e., on side slopes, and absence or reduced amount of larger chalk fragments has been used to differentiate the material from the Lowestoft Formation and other superficial deposits where possible.

Brickearth

5.3.14 The BGS Lexicon of Named Rock Units states that, Brickearth typically varies from silt to clay, usually yellow-brown and massive. The BGS Memoir describes Brickearth as light sandy loam.

5.3.15 Material interpreted as Brickearth has been encountered in the exploratory holes. It is typically described as soft to firm, brown, sandy silt or clayey sandy silt.

Glaciolacustrine deposits (formerly known as lake deposits)

5.3.16 The BGS Lexicon of Named Rock Units typically describes Glaciolacustrine Deposits as being laid down in glacial lakes and comprising silt and clay, laminated / varved, commonly rich in organic matter, locally with interbedded peat.

5.3.17 Glaciolacustrine deposits have been differentiated from Interglacial Silt and Clay deposits by their presence within or on the Lowestoft formation.

5.3.18 Material interpreted as Glaciolacustrine Deposits has been encountered in the exploratory holes and is typically described as firm, brown, laminated clayey silt, and silty clay. The material appears to have generally been removed from beneath the existing alignment earthworks.

Interglacial silt and clay

5.3.19 The BGS Lexicon of Named Rock Units typically describes Interglacial Silt and Clay as interbedded or chaotic silt and clay deposits.

5.3.20 Interglacial Silt and Clay deposits have been differentiated from Glaciolacustrine Deposits by the absence of Lowestoft Formation at the deposits upper or lower boundary, i.e. low energy deposits downstream of the glaciers.

5.3.21 Material interpreted as Interglacial Silt and Clay has been encountered in exploratory holes and is typically described as laminated firm to stiff clayey silt

and laminated firm to stiff, fine sandy clayey silt. This material is often found as 5m+ thick homogenous deposits with little variation in grain size. The material appears to have generally been removed from beneath the existing alignment earthworks.

Lowestoft Formation (formerly known as boulder clay)

5.3.22 The BGS Lexicon of Named Rock Units states that, the Lowestoft Formation forms an extensive sheet of chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content and its thickness is extremely variable. The BGS Memoir describes the local Boulder Clay, now known as the Lowestoft Formation, as grey clay with chalk inclusions.

5.3.23 Material interpreted as Lowestoft Formation has been encountered in the exploratory holes. It is typically described as firm to stiff, mottled pale orange to brown, slightly sandy, gravelly, silty clay. The gravel commonly consists of chalk, flint, sandstone, quartzite and occasionally mudstone.

Glaciofluvial deposits (formerly known as glacial sand and gravel)

5.3.24 The BGS Lexicon of Named Rock Units typically describes the Glaciofluvial Deposits as, sand and gravel, locally with lenses of silt, clay or organic material. The Glaciofluvial deposits are typically encountered beneath the Lowestoft Formation, but also outcropping above, from beneath or within the Lowestoft Formation as discrete and often discontinuous beds.

5.3.25 Material interpreted as Glaciofluvial Deposits has been encountered in the exploratory holes. It is typically described as; loose to very dense, brown, orangish brown or yellowish-brown, sandy gravel with occasional cobbles, or slightly gravelly sand. The gravel commonly consists of predominately flint gravel with occasional chalk and quartzite gravel.

Kesgrave Catchment Subgroup

5.3.26 The BGS Lexicon of Named Rock Units states that, the Kesgrave Catchment Subgroup encompasses fluvial, lacustrine and organic deposits of the pre-diversionary River Thames, and the pre-glacial soils developed on such deposits. Most of the surviving deposits are fluvial gravels, with sedimentary structures indicating deposition by a braided river. Lacustrine silts and clays and organic peats are uncommon. The BGS Memoir describes the Kesgrave sands and gravels, now known as the Kesgrave Catchment Subgroup, as containing a high proportion of rounded flint, quartz and quartzite pebbles. Secondary calcareous concretions which envelop flints are developed in the upper part of the gravels.

5.3.27 It should be noted that the current BGS GeoIndex Onshore maps indicate both the Kesgrave Catchment Group and the younger Glaciofluvial deposits to be present beneath the Lowestoft Formation around Kelvedon, with the Kesgrave being generally present to the north beneath the proposed scheme. Materials of the Kesgrave Catchment Group were not encountered in the borrow pit GI. However, in order to differentiate these materials for the wider scheme, the following criteria has been applied:

- Glaciofluvial Deposits - more angular clasts, occasional chalk, and poorer sorting.
- Kesgrave Catchment Group - well rounded, no chalk. Gravel mostly flint, commonly quartz and quartzite. Upper surface can be affected by ancient soil formation giving a reddish colouration.

London Clay Formation

5.3.28 The BGS Lexicon of Named Rock Units states that, the London Clay Formation mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. It commonly contains thin courses of carbonate concretions ('cementstone nodules') and disseminated pyrite. It also includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation. At the base, and at some other levels, thin beds of black rounded flint gravel occur in places. Glauconite is present in some of the sands and in some clay beds, and white mica occurs at some levels.

5.3.29 The London Clay Formation has been encountered in the exploratory holes. Weathered London Clay is typically described as firm to stiff orangish brown with some grey mottling silty clay. Unweathered London Clay Formation is typically described as stiff grey silty clay.

5.4 Hydrogeology

Groundwater strikes and rises

5.4.1 Groundwater strikes or seepages were recorded in exploratory holes during all GIs. However, the use of water flush during rotary drilling meant determining groundwater strikes was not always possible. Trial pits typically reached 4m depth and therefore water strikes were less common. As such, it was generally in the window sample holes and cable percussive holes that the strikes were recorded as shown in Table 5.3.

Table 5.3 Water strikes per exploratory holes

Hole type	Total number of holes	No. of holes recording a water strike	% of holes recording a water strike
Cable percussion and rotary follow on (BH+RC)	85	19	22%
Cable percussion (BH)	170	69	41%
Trial pit (TP)	306	34	11%
Window sample (WS)	137	48	35%
All holes	698	170	24%

5.4.2 Where recorded in the GI, groundwater strikes/seepages were generally within 4m of the ground surface as shown in Table 5.4.

Table 5.4 Overview of water strikes depths

Water strike depth (mbgl)	No. of holes/trial pits
0 to 2	57
2 to 3	31
3 to 4	35
4 to 8	44
Deeper than 8	20

5.4.3 Where groundwater was encountered in the boreholes and window sample holes, the hole was left to stand, and the water level measured again after 20 minutes to record the rise in groundwater level. The data show that generally, little rise in the groundwater level was recorded in the 20 minutes, with a rise of less than 2m recorded in 59% of the boreholes measured. 28% of the boreholes measured showed a rise of 3m of greater, with the largest rise in BH+RC2220 of 12.07m.

Relationship to geology

5.4.4 The groundwater strike data per geology are summarised in Table 5.5. The data shows that groundwater has typically been encountered in granular deposits associated with the Glaciofluvial and River Terrace Deposits, but also within the Lowestoft Formation which often contains more granular layers of varying thickness.

Table 5.5 Geological horizon in which the water strikes were recorded

Horizon of water strike	No. of holes/trial pits
Alluvium	7
Head Deposits	0
River Terrace Deposits	26
Lowestoft Formation	46
Glaciofluvial Deposits	54
Made Ground	5
Interglacial Lacustrine Deposits	3
Kersgrave Catchment Subgroup	2

Groundwater monitoring – variation over time

5.4.5 Groundwater monitoring was undertaken with manual dip measurements at monthly intervals and by installing groundwater level data loggers in 99 boreholes within design sections 1 to 3 of the proposed scheme.

5.4.6 Data collected from boreholes within design sections 1 and 2 provides one full year of groundwater level information, between August 2020 and September 2021.

5.4.7 In general, the data from locations within design sections 1 and 2 indicated a general seasonality with maximum groundwater elevations recorded between January and March, following a gradual rise from October, with a slow decline in levels following this into summer 2021.

5.4.8 The data available for boreholes within design section 3 is limited to between May and September and no seasonal trends are observable.

5.4.9 The variation in levels observed can broadly be divided into two types of responses. Many location indicating gentle rises and falls in groundwater levels over the summer and winter months, with levels generally varying by between several cm's and 2m during the winter and summer months. Other locations indicated very 'flashy' responses, with rapid spikes in levels likely to be attributable to rainfall events, with a general rising in water levels during January to March also.

5.4.10 The most notable exception to these patterns is in BH+RC1164A where groundwater levels vary by up to 5m in response to individual rainfall events. BH+RC1164A is completed in clayey deposits at the base of the Lowestoft Formation with a screened interval from 5.5 to 9.0mbgl and this result may be linked to surface water ingress and the results should be treated with caution.

5.4.11 WS1507 also shows significantly more variation, with the borehole initially being recorded as dry over the summer of 2020 but with levels rising to the ground level between early October and mid-November 2020 in response to wetter conditions, and then falling again from April 2021. However, the hydrograph at this location shows unusual responses and the results should also be treated with caution.

5.4.12 The general variation in the two types of responses could be attributable to whether the response zone is within a confined aquifer body or a shallow unconfined aquifer body, although some of the flashy responses may also be due to surface water infiltration at or in the near vicinity of the monitoring well.

5.4.13 In the vicinity of CH18+500 to 21+000 the groundwater level data loggers (including those installed for borrow pits) show an unusual water level response with rapid rises and falls in the water level of around 0.5m. Although no large abstractions (such as that required for quarry dewatering) have currently been identified in this area there are several licenced groundwater abstractions relating to agricultural irrigation. Assessment of dewatering impacts relating to cuttings and widenings in this area has considered the presence of the irrigation wells. However, it is noted that the screened section of these wells is close to surface, approximately 1m bgl, and hence they may be responding to surface water infiltration rather than groundwater abstractions.

5.4.14 For those boreholes and window sample holes completed as groundwater monitoring points and can be readily accessed, manual measurements of groundwater levels have been undertaken on an approximately monthly basis. Similar to the groundwater level logger data, the manual dip measurements show that groundwater levels do not vary to a great extent over time. However, it should be noted that the data were collected over a relatively short period (in some cases only 2 dip values are available) and are unlikely to record longer term very dry or wet periods which may increase the range in groundwater levels.

Groundwater monitoring – depth to groundwater

5.4.15 As summarised in Table 5.6, the available groundwater monitoring results show that measured groundwater levels are typically within 4m of the ground surface in all phases with the majority of shallowest groundwater levels found within 2m of the ground surface. There is no clear pattern to the distribution of the depth to groundwater levels across the proposed scheme as a whole, which is a result of heterogeneity of the superficial materials and the discontinuous nature of some of the water bearing layers.

Table 5.6 Minimum depth to groundwater recorded in groundwater monitoring points

Shallowest groundwater level recorded (mbgl)	No. of boreholes
0 to 2	127
2 to 4	58
4 to 6	29
>6	30

Groundwater flow directions

5.4.16 Groundwater levels as mAOD indicate that groundwater levels generally reflect the ground surface contours. Groundwater flows from the interfluves to the lower-lying valleys of the major rivers including the River Chelmer, River Brain, River Blackwater, Domsey Brook and Roman River.

5.4.17 In the vicinity of junction 19, groundwater flows in a generally north to south direction with groundwater likely to be discharging to the River Chelmer. Measured groundwater levels fall from around 30mAOD adjacent to the existing A12 to the north of junction 19 to around 18mAOD to the west of Springfield Business Park.

5.4.18 In the centre of the Phase 1 GI area, the highest groundwater levels (as mAOD) are recorded to the east of Hatfield Peveril in the vicinity of CH 17+500 at around 40mAOD. From this high point, the groundwater level data show that the groundwater flows in a radial pattern, likely to discharge to the River Ter to the west and southwest and the River Blackwater in the east and southeast.

5.4.19 The limited groundwater data available for the Phase 3 GI indicates that the highest groundwater elevations are located to the north east of Feering and towards Marks Tey, on the southern side of the A12 at approximately 35 to

40mAOD, with lower elevations towards Kelvedon and the River Blackwater, indicating groundwater flows are likely to discharge in this direction.

Permeability testing – results

5.4.20 Hydraulic conductivity (permeability) tests were undertaken in 69 standpipes following borehole development as shown in Table 5.7. However, due to various reasons as shown in the table, the data could not be analysed to produce hydraulic conductivity values although the response of water levels gives an indication of whether the formation tested has a relatively high or low permeability. This qualitative assessment has also been used to assess the likely drainage characteristic at each location and horizon.

Table 5.7 Summary of permeability tests

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH+RC1104	London Clay	Rising	No change in water level in 12 minutes. Low permeability.	Practically impervious
		Falling	Insufficient change to calculate permeability. Low permeability.	
BH+RC1109 Shallow	Made Ground (gravelly clay)	N/A	Borehole dry. Water added and soaked away in 40 minutes but not possible to analyse.	Good
BH+RC1109 Deep	Gravel (Glaciofluvial)	Falling	Reached rest level within 50 secs but data too noisy to assess. High permeability.	Very good
BH+RC1117	Mixed deposits but includes River Terrace Deposits	Falling	Not analysed as test in well screen. Data shows fall in level to rest level in approximately 15 mins. Moderate to low permeability.	Good
BH+RC1161 Shallow	Made Ground (gravelly clay)	N/A	Borehole dry. Water added and 1.66m of water soaked away in 60 minutes but not possible to analyse.	Poor
BH+RC1161 Deep	Sand and gravel (Glaciofluvial)	Falling	Displacement not discernible from background noise of logger. High permeability.	Very good
BH+RC1162	London Clay	Falling	Not analysed as test in well screen. Data show little fall in level in 30 mins. Low permeability.	Practically impervious
BH1159	Mixed deposits but includes Glaciofluvial	Falling	Not analysed as test in well screen. Data show little fall in level in 30 mins. Low permeability.	Poor
WS1428	Clay (Lowestoft) overlying Gravel (Glaciofluvial)	N/A	Borehole dry. Water added and 1.46m of water soaked away in 4 minutes but not possible to analyse.	Good

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
WS1435b	Sand and gravel (River Terrace Deposits)	Falling	Not analysed. Water level recovered within 12s of placing slug. High permeability.	Very good
		Rising	Not analysed. Water level recovered within 7s of withdrawing slug. High permeability.	
WS1512	Clay (Lowestoft Formation)	Falling	Insufficient fall in head to calculate permeability value. Low permeability.	Poor
BH+RC1164a	Clay (Lowestoft Formation)	Falling	No change in water level in 75 minutes. Low permeability.	Practically impervious
BH+RC1165	1m gravel (Lowestoft Formation) overlying London Clay	Falling	Not analysed as test in well screen. Data show fall in level to rest level in approximately 20 mins/. Low to moderate permeability.	Good
WS1403	Gravel (Glaciofluvial)	Falling	Not analysed as test in well screen. Low to moderate permeability.	Good
WS1430	Clay (Lowestoft Formation)	Falling	No change in water level in 60 minutes. Low permeability.	Practically impervious
WS1506	Clay (Head over London Clay)	Falling	No change in water level in 60 minutes. Low permeability.	Practically impervious
WS1509	Clay (Lowestoft Formation)	Falling	No change in water level in 15 minutes. Low permeability.	Poor
		Rising	No change in water level in 14 minutes. Low permeability.	
BH+RC2203	Clay (Lowestoft Formation)	Falling	No change in water level in 60 minutes. Low permeability	Practically impervious

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH+RC2272A	Gravel and Clay (River Terrace Deposits)	Falling	Water level falls 10cm in 20 minutes. Low to moderate permeability	Good
		Rising	Water level recovers 5cm in 20 minutes. Low to moderate permeability	
BH+RC2273 Shallow	Clay (Alluvium)	Rising	Water level returns to rest water level in 10 minutes. Moderate permeability	Good
BH+RC2273 Deep	Sand (River Terrace Deposits and Glaciofluvial)	Rising	Water level recovers 9cm in 10 minutes. Moderate permeability.	Good
BH+RC2274A	Gravel (River Terrace Deposits)	Rising	Not analysed as test in well screen. Water level returns to rest water level in 3 minutes. High permeability	Good
BH+RC2204 Shallow	Silt, sand and clay (River Terrace Deposits)	Falling	Water level returns to rest water level in 35mins. Low to moderate permeability	Poor
		Rising	Water level returns to rest water level in 35mins. Low to moderate permeability	
BH+RC2204 Deep	Clay, sand and silt (River Terrace Deposits)	Falling	Water level recovers 40cm in 45 minutes. Low permeability. Permeability likely mostly associated with thin sand horizons.	Poor
		Rising	Water level recovers 30cm in 25 minutes. Low permeability. Permeability likely mostly associated with thin sand horizons.	
BH+RC2269 Shallow	Silt (Lowestoft Formation)	Falling	Well too narrow for slug so water added. Water level returns to rest water level in 30 minutes. Low to moderate permeability	Poor
		Rising	Well too narrow for slug so water pumped out. Water returns to rest water level in 30 minutes. Low to moderate permeability	

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH+RC2269 Deep	Sand (Glaciofluvial)	Falling	Water level returns to rest water level in 2 minutes. High permeability	Good
BH+RC2640	Sand (River Terrace Deposits)	Falling	Water fall by 58cm in 20 minutes. Moderate permeability	Good
		Rising	Water recovers by 56cm in 15 minutes. Moderate permeability	
WS2408	Clay (Lowestoft Formation)	Falling	Insufficient fall in head to calculate permeability value, no change in 25 minutes. Low permeability.	Poor
		Rising	Insufficient fall in head to calculate permeability value. Low permeability.	
WS2446	Silt (Lowestoft Formation)	Falling	2.58m of water drains in 30 minutes. Low to moderate permeability.	Poor
WS2461 Shallow	Sand (Made Ground)	Falling	Insufficient fall in head to calculate permeability value. Low permeability.	Poor
		Rising	Insufficient fall in head to calculate permeability value. Low permeability.	
	Sand, clay and silt (Made Ground and River Terrace Deposits)	Falling	Insufficient fall in head to calculate permeability value. Low permeability.	Poor
		Rising	Insufficient fall in head to calculate permeability value. Low permeability.	
WS2461 Deep	Sand (River Terrace Deposits)	Falling	Water returns to rest water levels in 25 minutes. Moderate permeability.	Good
		Rising	Water recovers by 3.55m in 35 minutes. Moderate permeability.	

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
WS2462	Sand (River Terrace Deposits) overlying Clay (Lowestoft Formation)	Falling	Not analysed as test in well screen. 2.48m of water drains in 30mins, then stabilises. Moderate permeability in RTD, low permeability in LWS.	Good (River Terrace Deposits only)
WS2465B	Silt (Lowestoft Formation)	Falling	Water levels static for 5mins before dropping. Low permeability	Poor
BH+RC2225 Shallow	Silt and sand (River Terrace Deposits)	N/A	Borehole dry. Water added and 1.64m soaked away in 30 minutes but not possible to analyse. Moderate permeability	Good
BH+RC2225 Deep	Gravel (River Terrace Deposits) overlying silt and clay (Lowestoft Formation)	Falling	Not analysed as test in well screen. Water level falls 7cm in 30 minutes. Low to moderate permeability	Poor
		Rising	Not analysed as test in well screen. Water level recovers 5cm in 30 minutes. Low to moderate permeability.	
BH+RC2261	Clay (Lowestoft Formation)	Falling	Water level fell in less than 1 minute. Results to be treated with caution. Very gravelly layer at 17.6mbgl possibly responsible.	Not assessed
		Rising	Water level recovered in less than 1minute. Results to be treated with caution. Very gravelly layer at 17.6mbgl possibly responsible.	
BH+RC2266 Shallow	Sand (River Terrace Deposits)	N/A	Borehole dry. Water added and 3.29m soaked away in 30 minutes but not possible to analyse. Moderate permeability	Good
BH+RC2266 Deep	Silt (Lowestoft Formation) overlying gravel (Glaciofluvial)	Falling	Water level fell to rest water levels in less than 5 mins. Moderate permeability.	Good

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH+RC2606	Silt (Lowestoft Formation)	Falling	Water level fell to rest water levels in 13 minutes. Low to moderate permeability.	Poor
		Rising	Water level recovered to rest water levels in 22 minutes. Low to moderate permeability.	
BH+RC2620 Shallow	Silt (Made Ground)	N/A	Borehole dry. Water added but very rapidly drained away.	Good
BH+RC2620 Deep	Clay and sand (River Terrace Deposits)	N/A	Borehole dry. Water added but very rapidly drained away.	Good
BH2263	Gravel (River Terrace Deposits)	N/A	Borehole dry. Water added and drained away in 1 min. High permeability	Good
BH2607	Sand (River Terrace Deposits)	Falling	Not analysed as test in well screen. 1.57m of water drained in 30 mins. Moderate permeability	Good
BH2623	Sand (River Terrace Deposits)	Falling	Water returns to rest water level in 2.5mins. Moderate permeability.	Good
BH2645	Gravel (River Terrace Deposits)	N/A	Borehole dry. Water added but very rapidly drained away. High permeability	Very good
BH+RC3217	Sand and gravel (Kersgrave Catchment subgroup)	Rising	Unable to reduce head sufficiently. High permeability.	Very good

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH3012	Clay (road embankment and Lowestoft formation)	Falling	Borehole dry. 0.55m drained in 30 minutes. Low to moderate permeability	Good
	Clay (Lowestoft formation)	Rising	Water did not return to rest water level within an hour.	Poor
BH+RC3204	Gravel and sand (glaciofluvial deposits)	Falling	Water returns to rest water level in 3.4mins. High Permeability	Very good
BH+RC3207	Sand (glaciofluvial deposits)	Falling	Water level fell 5.93m in 18.97 minutes. High permeability	Good
		Rising	Water level rose 4.91m in 21.4 minutes. High permeability	Good
	Clay and sand (head deposits underlain by river terrace deposits)	Rising	Water rose 1.85m in 30 minutes. Moderate permeability	Good
BH+RC3216	Sand and gravels (glaciofluvial deposits)	Rising	Unable to lower level to carry out test. Very high permeable.	Very Good
BH3003	Clay (London clay)	Rising	Water rose 0.13m in 74 minutes. Very low permeability.	Practically impervious
BH3004	Clay and gravel (river terrace deposits)	Rising	Water level within slotted section. Rising head test completed by pumping. Water rose 1.57m in 26.65 minutes. Moderate permeability	Good
BH3005	Gravel (glaciofluvial deposits), underlain by clay (London clay formation) from 5.9m	Rising	Water level rose 0.59m in 58 minutes. Moderate to low permeability	Poor

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH3006	Gravel (glaciofluvial deposits)	Rising	Water level within slotted zone, unable to calculate intake factor. Water rose 0.19m in 3 minutes. High permeability	Good
BH3007	Clay and sand (Lowestoft formation and glaciofluvial deposits)	Falling	standing water level within slotted zone, unable to calculate intake factor. Water level too low for rising head test. Water level fell 0.84m in 25 minutes. Moderate to low permeability	Poor
	Clay (Lowestoft formation)	Falling	Water level within slotted zone, unable to calculate intake factor. Water too low for rising head test. Water fell 2.14m in 30 minutes. Moderate permeability	Poor
BH3008	Sand and gravel (glaciofluvial deposits)	Rising	Water level rose 0.26m in 1.65 minutes. High permeability.	Good
	Sand (glaciofluvial deposits)	Falling	Water level within slotted zone, unable to calculate intake factor. Falling head test complete to demonstrate infiltration. Water level fell 1.07m in 5 minutes.	Very good
BH3009	Clay (Lowestoft formation)	Rising	Rising head test completed following pumping. Water level rose 0.16m in 30.43 minutes. Low permeability.	Practically impervious
BH3013	Clay (Lowestoft formation)	Falling	Water level fell 0.13m in 33.08 minutes. Low permeability.	Poor
BH3017	Clay and sand (River terrace deposits underlain by Lowestoft formation)	Falling and rising	Insufficient change in water level to calculate permeability. Low permeability.	Practically impervious
BH3027	Sand and gravel (glaciofluvial deposits)	Rising	No test conducted due to quick recharge. Water level remaining static despite continuous pumping. High permeability.	Very good

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH3032	Clay and gravel (Lowestoft formation and glaciofluvial deposits)	Falling	Water level fell 1.44m in 30 minutes. Low – moderate permeability	Good
		Rising	Water level rose 0.98m in 30 minutes. Low – moderate permeability.	Poor
BH3035	Gravel, sand and clay (glaciofluvial deposits)	Falling	Water level fell 0.41m in 25 minutes. Moderate permeability.	Good
		Rising	Water level rose 2.2m in 60 minutes. Moderate to low permeability.	Poor
	Clay (Lowestoft formation)	Falling	Very fast loss of head, results should be treated with caution. Water level fell 0.39m in 3.07 minutes. High Permeability.	Good
		Rising	Very fast rise in head, results should be treated with caution. Water level rose 0.41m in 7 minutes. High Permeability.	Good
BH3036	Gravel (Glaciofluvial deposits)	Falling	Infiltration rate too fast to determine permeability. High permeability	Good
		Rising	Pumping rate only reduced head by 3cm, insufficient head to determine permeability. High permeability.	Very good
	Clay (Lowestoft formation)	Falling	Water level insufficient for rising head test. 25 litres of water added to demonstrate infiltration. Water level fell 1.38m in 11 minutes. High permeability (although result should be treated with caution).	Poor
BH3037	Clay (Lowestoft formation)	Falling	Water level fell 0.42m in 30 minutes. Moderate to low permeability	Poor
		Rising	Water level rose 0.48m in 30 minutes. Moderate to low permeability	Poor
BH3041	Clay and gravel (Lowestoft formation underlain by glaciofluvial deposits)	Falling	Water level insufficient for rising head test. 25 litres of water added to demonstrate infiltration. Water level fell 0.41m in 10 minutes.	Good

Borehole	Geology of tested section	Rising or falling head test	Comment	Likely drainage characteristic
BH3045	Sand and gravel (Kersgrave Catchment subgroup)	Falling	50 litres of water added to demonstrate infiltration. Water level fell 0.43m in 5 minutes.	Good
	Clay and sand (made ground)	Falling	Borehole dry. 20 litres of water added to demonstrate infiltration. Water level fell 1.41m in 4 minutes. High permeability.	Good
BH3046	Clay and sand (Lowestoft formation underlain by glaciofluvial deposits)	Falling	Borehole dry. 50 litres of water added to demonstrate infiltration. Water level fell 0.14m in 10 minutes. Moderate permeability	Poor
BH3012	Clay (road embankment and Lowestoft formation)	Falling	Borehole dry. Water dropped 0.55m in 30 minutes. Moderate to low permeability	Poor
	Clay (Lowestoft formation)	Rising	Water rose 0.59m in 60 minutes. Low permeability.	Poor
BH3043	Sand and gravel (Glaciofluvial Deposits)	Falling	Water level insufficient for rising head test. 25 litres of water added to demonstrate infiltration. Water level fell 0.23m in 14 minutes. High Permeability.	Good

5.5 Assessment of potential contamination

5.5.1 The following section provides a summary of the assessment for potential contamination based on information from the ground investigation. The assessment has been undertaken in line with Land Contamination: Risk Management (LCRM) published by the Environmental Agency (2020). The document provides a technical framework for applying a risk assessment in the form of a Conceptual Site Model (CSM) which supports the identification of plausible contaminant linkages. The preliminary CSM and risk assessment developed as part of the A12 Chelmsford to A120 PSSR has been refined based on data collected during the ground investigation (see Table 5.20).

Soil

5.5.2 The soil data has been screened against the Category 4 Screening Levels (C4SLs) for commercial/industrial use. Where C4SL criteria are not available, Suitable for Use Levels (S4ULs) have been used. C4SLs have been published for only six key indicators of contaminated land including arsenic, benzene, benzo(a)pyrene, cadmium, chromium (VI) and lead and are based on a sandy loamy soil with 6% Soil Organic Matter (SOM).

5.5.3 The generic screening criteria for soils highlighted above have been published for a variety of land uses and soil organic matter (SOM) levels. Due to the end use of the proposed scheme as a road, the commercial / industrial generic screening criteria has been applied. A SOM concentration of 1% has been applied to the screening as the average SOM in all the samples was 1.3%. All of the soil samples were tested for total organic carbon (TOC). To convert to SOM, a conversion factor of 1.72 has been applied to the TOC data.

Soil leachate

5.5.4 To assess potential risks to controlled waters from leachable contaminants present in soil, a comparison of the soil leachate analysis results was undertaken against the relevant screening criteria for controlled waters – the Environmental Quality Standards (EQS) for freshwater waters (annual average) and Drinking Water Standards (DWS) were used where available.

Groundwater

5.5.5 Similar to soil leachate samples, assessment of potential risks to groundwater have been undertaken by comparing groundwater samples analysis results against the relevant screening criteria for controlled waters – EQS and DWS. As groundwater underlying the proposed scheme are likely to provide baseflow to surrounding surface waters, the results were compared against the EQS. Samples collected from standpipe locations where source protection zones have been identified were compared against the DWS.

5.5.6 It should be noted that the EQS for copper, lead, manganese, nickel, and zinc are compared against the bioavailable concentration of the receiving water body (not the dissolved concentration). The bioavailable concentrations are dependent on other physio-chemical components of the receiving water body such as pH, Dissolved Organic Carbon (DOC) and calcium. This has been

calculated from the dissolved concentration using the Metal Bioavailability Tool (M-BAT).

Made ground

5.5.7 Granular and cohesive Made Ground was classified in all exploratory locations except for TP1553. Generalised descriptions and thicknesses are summarised in Table 5.8 below. Embankment fill material was also encountered during the ground investigation and categorised as either granular or cohesive. A summary of the embankment fill is given below. The soils mainly comprise brown clay with flint gravel with occasional fragments of chalk, brick and concrete.

Table 5.8 Summary of the made ground encountered

Made ground type	Min depth top (m bgl)	Max depth base (m bgl)	Generalised description
Cohesive	-	3.8	Brown slightly sandy gravelly CLAY. Gravel sized fragments are generally subangular to subrounded of flint occasionally chalk, mudstone, quartzite, limestone, asphalt, brick, concrete and plastics.
Granular	-	4.1	Brown clayey SILT/SAND/GRAVEL. Gravel sized fragments are generally subangular to subrounded of flint occasionally chalk, quartzite, limestone, andesite, asphalt, brick, concrete and plastics.
Embankment Fill - Cohesive	0.3	7.0	Brown sandy gravelly CLAY. Gravel sized fragments are generally subangular to rounded of flint and chalk occasionally mudstone, quartzite, asphalt, brick and concrete
Embankment Fill - Granular	-	8.3	Brown very gravelly/sandy GRAVEL/SAND. Gravel sized fragments are generally subangular to rounded of flint occasionally mudstone, quartzite, limestone, asphalt, brick, plastics and metals.

Visual and olfactory evidence of land contamination

5.5.8 During all GIs there were no instances of visual evidence of contamination within Made Ground other than occasional pieces of plastics, metals and other anthropogenic fragments. However, these do not constitute a significant contaminant risk.

5.5.9 Olfactory evidence of contamination was noted on a number of occasions and is detailed in Table 5.9 below.

Table 5.9 Olfactory evidence of contamination

Location ID	Depth top (m)	Depth base (m)	Description (geological formation)	Setting
GI Phase 1				
BH+RC1106	0.40	0.50	Asphalt bound layer with a strong hydrocarbon odour.	Cored through pavement of Station Road, Hatfield Peverel
BH+RC1106	0.50	0.90	Dark brown and brown slightly sandy angular and subrounded flint GRAVEL with hydrocarbon odour. (Glaciofluvial Deposits)	
BH+RC1164A	3.50	6.00	Firm to stiff brown sandy gravelly silty CLAY. Gravel is subangular to rounded fine to medium chalk and flint. Frequent brown organic pockets and occasional fine black carbonaceous traces. Hydrocarbon odour. (Made Ground – Embankment Fill)	Cored through A12 Northbound pavement
BH1180	0.85	1.20	Firm dark brown mottled dark grey slightly sandy gravelly CLAY. Gravel is angular to subrounded fine to coarse chalk rarely flint and brick fragments. Slight hydrocarbon odour. (Made Ground – Embankment Fill)	Cored through A12 Northbound pavement
WS1435B	0.50	0.80	Dark brown sandy gravelly SILT with occasional rootlets and rare flint and tarmac cobble sized fragments (up to 80mm). Gravel is subangular and subrounded fine to coarse flint, quartzite, tarmac and brick fragments. 0.50 - 0.80m: Tarmac/bitumen odour. (Made Ground)	In agricultural field adjacent to southbound A12.
WS1640B	1.20	3.50	Stiff grey mottled yellowish-brown gravelly sandy silty CLAY. Gravel is subangular to rounded fine and medium chalk, flint and occasional red mudstone fragments. Occasional pockets of grey to brown organic material. Slight hydrocarbon odour. (Made Ground – Embankment Fill)	Cored through A12 Northbound pavement

Location ID	Depth top (m)	Depth base (m)	Description (geological formation)	Setting
GI Phase 2				
BH+RC2201A	1.20	2.40	Medium dense orangish brown slightly clayey very sandy subangular to rounded fine to coarse flint GRAVEL. Faint possible hydrocarbon odour. (Made Ground – Road Embankment)	Road embankment fill behind the River Ter Bridge abutment on the A12 Southbound.
	2.40	4.10	Stiff orangish brown gravelly sandy silty CLAY with low angular to subangular flint cobble content and faint possible hydrocarbon odour, Gravel is subangular to rounded fine to coarse chalk and flint. (Made Ground – Road Embankment)	
BH+RC2244	8.40	10.20	Dense light grey gravelly fine and medium SAND. Gravel is subangular and subrounded fine and medium flint. 9.10 - 9.20m: Gravel is angular to rounded fine and medium chalk and flint. Abundant pockets of black organic material (up to 10mm) and faint hydrocarbon odour. (River Terrace Deposits)	In agricultural field approximately 170m south-east of the A12. Nearest potential source of contamination is a fuel station located 500m to the north-east.
GI Phase 3				
IP3902	1.20	1.30	Soft becoming firm orangish brown slightly sandy slightly gravelly silty CLAY with frequent becoming rare rootlets. Gravel is subangular to rounded fine to coarse flint and quartzite. 0.45m: White 80mm diam plastic pipe. 1.30 - 1.60m: Black. Strong hydrocarbon odour. (Made Ground)	Olivers Bridge on the south-eastern underside. Location completed to confirm pile cap structure.

Location ID	Depth top (m)	Depth base (m)	Description (geological formation)	Setting
IP3904	1.50	1.60	Yellowish brown silty sandy rounded fine and medium flint and angular and subangular medium and coarse concrete GRAVEL. Rare lengths of timber (up to 300mm long) 1.50m: Gravel is greyish brown with rare black staining up to 35mm. Faint hydrocarbon odour. Thin oil slick on seeping groundwater. (Made Ground)	junction 20a northbound exit slipway.

Headspace testing

5.5.10 Headspace testing for volatile organic vapours was undertaken on each geo-environmental sample to aid in the scheduling process.

Soil assessment

5.5.11 A total of 378 samples of soil were tested for the general soil suite (Suite E1) which included analysis on inorganics, metals, semi-metalloids, TPH (including BTEX); PAH and asbestos screen and quantification. 17 samples were analysed for the expanded Suite E2 which include VOC and SVOC. 10 further samples were analysed for expanded Suite E3 which includes PCBs.

5.5.12 All concentrations of inorganics, metals, semi-metalloids, TPH (including BTEX), PCBs, VOC and SVOC were recorded below the S4UL commercial/industrial for generic assessment criteria or C4SL for commercial land use where available.

5.5.13 There were some exceedances for speciated PAH. These exceedances are summarised in Table 5.10 below. The exceedances in the natural deposits at BH+RC1106 were likely caused by the migration of these contaminants from the overlying historical road asphalt during construction. The historical asphalt is listed in Tables 5.15 and 5.16.

5.5.14 In the Phase 2 GI (design section 2 of the proposed scheme), none of the soil samples tested exceeds the generic screening criteria for soils.

Table 5.10 Soil samples exceeding the commercial/industrial guideline PAH values

Location ID	Depth top (mbgl)	Depth base (mbgl)	Description (geological formation)	Speciated PAH	Commercial / industrial S4UL (mg/kg)	Result (mg/kg)
GI Phase 1						
WS1435B	0.50	0.80	Dark brown sandy gravelly SILT with occasional rootlets and rare flint and tarmac cobble sized fragments (up to 80mm). Gravel is subangular and subrounded fine to coarse flint, quartzite, tarmac and brick fragments. 0.50 - 0.80m: Tarmac/bitumen odour. (Made Ground)	Benzo(b)fluoranthene	44	120
				Benzo(a)pyrene	35	85
				Dibenz(a,h)anthracene	3.5	12
BH+RC1106	0.90	1.00	Brown slightly gravelly silty fine to coarse SAND. Gravel is angular to subrounded flints. (Glaciofluvial Deposits)	Benzo(b)fluoranthene	44	56
				Benzo(a)pyrene	35	71
				Dibenz(a,h)anthracene	3.5	7.4
GI Phase 3						
BH+RC3206	0.20	0.40	Very soft dark brown very soft slightly sandy slightly gravelly silty CLAY with abundant rootlets. Gravel is angular to subrounded fine and	Benzene	27	41

Location ID	Depth top (mbgl)	Depth base (mbgl)	Description (geological formation)	Speciated PAH	Commercial / industrial S4UL (mg/kg)	Result (mg/kg)
			medium flint and quartzite. (Made Ground)			
BH3021	0.20	0.40	Soft light brown slightly sandy slightly gravelly CLAY with a low subangular concrete cobble content. Gravel is subangular to rounded fine to coarse flint, chalk and rarely concrete. (Made Ground)	Naphthalene	190	350

Asbestos screening and quantification

5.5.15 Cement bound asbestos was identified in one sample detailed in Table 5.11 below. There is no guideline limit for asbestos with respect to human health.

5.5.16 Asbestos free fibres were not identified in any sample.

Table 5.11 Soil samples containing asbestos fibres

Location ID	Depth top (mbgl)	Depth base (mbgl)	Description (geological formation)	Asbestos containing material (ACM) detected	Mineral form	Total % asbestos
BH3045	0.50	0.80	Blackish brown slightly gravelly slightly clayey silty SAND with abundant tile and brick (up to 70mm) and occasional rootlets. Gravel is subangular to rounded fine to coarse flint, sandstone and coal. (Made Ground)	Hard/Cement Type Material	Chrysotile	0.166

Soil leachate assessment

5.5.17 Soil leachability testing has been undertaken on a total of 148 samples to assess the potential for the soil underlying the proposed scheme to act as a source of contamination to controlled waters (groundwater and surface water). Soil samples were selected based on locations where sensitive aquifers underlie the proposed scheme and locations in close proximity to surface waters. The results have been compared against the relevant screening criteria for controlled waters risk assessment – EQS and DWS separately to assess risk to controlled waters and groundwater SPZs respectively.

5.5.18 The leachate laboratory test method is considered to be very aggressive and not necessarily representative of the geochemical regime at the site. The results provide an indication of the potential metal leachability but do not necessarily constitute a clear risk of potential harm to controlled waters.

Soil leachate compared against environmental quality standards

5.5.19 The soil leachate exceedances of the EQS guideline values are shown in Table 5.12 below.

5.5.20 There are elevated concentrations of specific metals (Chromium; Copper; Lead; Zinc). A total of 107 samples out of 148 samples recorded no exceedance of any metals.

5.5.21 A number of PAH compounds exceeded the guideline values at location BH+RC1106 in Glaciofluvial deposits. These are thought to be associated with the overlying asphalt and soils which had a hydrocarbon odour during the time drilling. General assessment of asphalt encountered on the proposed scheme including the sample from BH+RC1106 is detailed in Tables 5.15 and 5.16.

Table 5.12 Soil leachate samples exceeding the EQS guideline values

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
GI Phase 1					
BH+RC1106	0.90 – 1.00	Brown slightly gravelly silty fine to coarse SAND. Gravel is angular to subrounded flints. (Glaciofluvial Deposits)	Copper (Bioavailable)	1	37 (1.7)
			Naphthalene	2	52
			Anthracene	0.1	3
			Fluoranthene	0.0063	1.6
			Benzo(b)fluoranthene	0.00017	1.6
			Benzo(k)fluoranthene	0.00017	0.63
			Benzo(a)pyrene	0.00017	1.4
			Indeno(1,2,3cd) pyrene	0.00017	0.99

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH+RC1108	0.65 – 0.75	Yellowish brown gravelly fine to coarse SAND. Gravel is subangular to rounded fine to coarse flint. (Glaciofluvial Deposits)	Lead (Bioavailable)	1.2	8 (2.7)
BH+RC1109	0.50 – 0.60	Brown becoming light brown slightly clayey, locally clayey sandy locally very sandy angular to subrounded fine to coarse flint, concrete and limestone GRAVEL fragments with rare medium gravel sized fragments of plastic and metal and a low angular concrete cobble content. Frequent roots (up to 5mm) and rootlets (Made Ground)	Lead (Bioavailable)	1.2	21 (7.87))
			Zinc (Bioavailable)	10.9	23 (11.9)
	1.05 – 1.15		Lead (Bioavailable)	1.2	14 (5.2)
BH+RC1160a	0.60 – 0.80	Greyish brown slightly clayey sandy subangular to rounded fine to coarse brick, flint and ceramic GRAVEL (Made Ground)	Copper (Bioavailable)	1	17 (2.0)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH+RC1180	0.60 – 0.80	Firm greyish brown slightly sandy slightly gravelly CLAY. Gravel is angular to subrounded fine to coarse chalk rarely flint and brick fragments. (Made Ground – Embankment Fill)	Copper (Bioavailable)	1	25 (1.5)
			Lead (Bioavailable)	1.2	6 (1.4)
CPT1310	0.60 – 0.70	Greenish brown gravelly medium and coarse SAND. Gravel is subangular and subrounded fine to coarse flint. (Made Ground)	Chromium (III)	4.7	19
			Lead (Bioavailable)	1.2	12 (4.5)
	1.00 – 1.10		Chromium (III)	4.7	6.1
			Lead (Bioavailable)	1.2	8.8 (3.3)
TP1559	0.10 – 0.20	Soft brown sandy gravelly silty CLAY. Gravel sized fragments are subangular to rounded fine to coarse flint and grey limestone. Occasional brick fragments. (Made Ground)	Copper (Bioavailable)	1	11 (1.0)
TP1629	0.70 – 0.80	Light brown and dark brown slightly gravelly slightly sandy silty CLAY with rare pockets (up to 150mm) of light orangish brown silty clay. Gravel is subangular and subrounded fine to coarse flint (Lowestoft Formation)	Lead (Bioavailable)	1.2	5.7 (1.2)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
WS1405	0.40 – 0.45	Dark grey sandy angular and subangular fine to coarse crystalline GRAVEL sized fragments. (Made Ground)	Copper (Bioavailable)	1	30 (1.2)
			Lead (Bioavailable)	1.2	8 (1.4)
WS1425	0.60 – 0.70	Greenish brown gravelly medium and coarse SAND. Gravel is subangular and subrounded fine to coarse flint. (Glaciofluvial Deposits)	Chromium (VI)	3.4	6.4
WS1426b	0.80 – 0.90	Brown and yellowish brown slightly clayey very sandy subangular to rounded fine to coarse flint GRAVEL with a low subangular flint cobble content. (Glaciofluvial Deposits)	Lead (Bioavailable)	1.2	2 (4.5)
GI Phase 2					
BH+RC1182	0.70 – 0.80	Black to grey sandy subangular and subrounded fine to coarse granite GRAVEL. (Made Ground)	Cyanide (Total)	1.0	2.4
			Lead	1.2	1.3
BH+RC2204	0.95 – 1.00	Medium dense dark brown slightly silty fine to coarse SAND. (Made Ground)	Cyanide (Total)	1.0	2.0

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH+RC2225	0.20 – 0.40	Greyish brown clayey slightly sandy slightly gravelly SILT. Gravel is subangular and subrounded fine and medium flint. (Made Ground)	Copper (Bioavailable)	1.0	29 (4.68)
			Lead (Bioavailable)	1.2	3.5 (2.2)
BH+RC2226	0.25 – 0.35	Brown slightly gravelly clayey SILT. Gravel is angular to rounded fine and medium flint and rare brick. (Made Ground)	Copper (Bioavailable)	1.0	16.0 (2.6)
BH+RC2266	0.20 – 0.30	Orange brown sandy gravelly silty CLAY. Gravel is subangular and subrounded fine to coarse flint. (Glaciofluvial Deposits)	Copper (Bioavailable)	1.0	32.0 (3.6)
BH2603	0.20 – 0.30	Brown slightly sandy SILT. (Made Ground)	Copper (Bioavailable)	1.0	35 (2.2)
BH2623	0.20 – 0.30	Grass over brown slightly gravelly SILT. Gravel is angular to rounded fine and medium flint with rare brick and concrete fragments. (Made Ground)	Copper (Bioavailable)	1.0	17.0 (2.8)
			Lead (Bioavailable)	1.2	2.0 (1.4)
BH2640	1.00 – 1.10	Orange slightly gravelly SAND. Gravel is subangular and subrounded fine and medium limestone. (River Terrace Deposits)	Cyanide (Total)	1.0	1.4

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH2645	0.00 – 0.20	Firm dark brown slightly gravelly clayey SILT. Gravel is angular and subangular fine and medium flint with rare brick fragments. (Made Ground)	Lead (Bioavailable)	1.2	4.0 (2.5)
CPT2343	0.10 – 0.30	Dark brown slightly sandy slightly gravelly clayey SILT with rare rootlets. Gravel is subangular and subrounded fine to coarse flint. (Made Ground)	Copper (Bioavailable)	1.0	6 (1.0)
			Lead (Bioavailable)	1.2	3.0 (1.8)
GI Phase 3					
BH+RC3205	0.30 – 0.40	yellowish brown slightly silty gravelly fine to coarse SAND with frequent angular to subrounded brick and concrete cobbles up to 120mm diam. Gravel is angular to rounded fine and medium flint and quartzite. (Made Ground)	pH	6 – 9	9.1
BH+RC3206	1.70 – 1.80	Medium dense dark orange slightly clayey sandy angular to rounded fine to coarse flint GRAVEL. (Made Ground – Road Embankment)	pH	6 – 9	9.6

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH+RC3218	0.55 – 0.65	Orangish brown gravelly to very gravelly fine to coarse SAND. Gravel is subangular to rounded flint. (Made Ground)	Cadmium	0.25	0.32
BH+RC3221	0.20	Firm dark brown slightly gravelly slightly sandy silty CLAY. Gravel is angular to rounded fine to coarse flint and quartzite with abundant angular fine to coarse brick fragments. (Made Ground)	Cyanide (Total)	1	2.7
	0.90	Very soft greyish brown mottled orangish brown slightly gravelly silty CLAY with frequent roots (up to 5mm diam.) and rootlets. Gravel is angular and subangular fine and medium flint and brick. (Made Ground)	Cyanide (Total)	1	2.8
BH3004	0.30 – 0.35	Soft dark brown mottled orangish light brown gravelly CLAY. Gravel is angular to subrounded fine to coarse of flint. (River Terrace Deposits)	Lead (Bioavailable)	1.2	6.20 (1.59)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH3007	0.10 – 0.30	Brown slightly gravelly sandy SILT with occasional angular cobbles of flint (65x70mm). Gravel is angular to subrounded fine to coarse flint. (Made Ground / Reworked Natural Deposits)	Lead (Bioavailable)	1.2	4.50 (1.56)
BH3011	0.50 – 0.70	Soft to firm light brown slightly sandy slightly gravelly CLAY with a low subangular flint cobble content. Gravel is subangular to rounded fine to coarse flint and chalk. (Made Ground)	Lead (Bioavailable)	1.2	8.00 (1.48)
BH3012	0.50 – 0.70	Yellowish brown clayey locally very clayey sandy subangular and subrounded fine to coarse GRAVEL of flint, concrete and chalk. (Made Ground)	Lead (Bioavailable)	1.2	24.00 (5.91)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH3024	2.80 – 2.90	Asphalt (~25mm) over slightly sandy GRAVEL with low subrounded concrete cobble content. Gravel is multi-coloured angular to subrounded fine to coarse flint, concrete and black probable asphalt. (Made Ground – Road Embankment)	pH	6 - 9	10.2
BH3035	0.00 – 0.20	Soft greyish brown slightly sandy slightly gravelly silty CLAY with occasional rootlets. Gravel is angular fine to coarse flint. (Made Ground / Reworked Natural Deposits)	Chromium (III)	4.7	4.7
BH3045	0.50 – 0.80	Blackish brown slightly gravelly slightly clayey silty SAND with abundant tile and brick (up to 70mm) and occasional rootlets. Gravel is subangular to rounded fine to coarse flint, sandstone and coal. (Made Ground)	Cadmium	0.25	0.36
			Lead (Bioavailable)	1.2	34.00 (4.91)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
BH3048	0.00 – 0.20	Soft dark brown sandy slightly gravelly CLAY with frequent rootlets. Gravel is subangular fine and medium flint. Occasional plastic bottle fragment and coffee cup lid. (Made Ground)	Lead (Bioavailable)	1.2	18.00 (3.85)
BH3054	0.40 – 0.60	Brown clayey sandy subangular and subrounded fine to coarse GRAVEL of flint, concrete and rarely chalk. (Made Ground)	pH	6 – 9	9.3
IP3901	0.00 – 0.10	Grass over very soft dark brown slightly sandy gravelly CLAY with frequent rootlets. Gravel angular to subrounded fine to coarse red brick, concrete and flint. (Made Ground)	Lead (Bioavailable)	1.2	7.90 (1.34)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
IP3902	1.20 – 1.30	Soft becoming firm orangish brown slightly sandy slightly gravelly silty CLAY with frequent becoming rare rootlets. Gravel is subangular to rounded fine to coarse flint and quartzite. 0.45m: White 80mm diam plastic pipe. 1.30 - 1.60m: Black. Strong hydrocarbon odour. (Made Ground)	Cyanide (Total)	1	1.5
IP3903	1.30 – 1.40	Soft grey mottled dark orange slightly sandy slightly gravelly CLAY. Gravel is angular coarse flint. (Alluvium)	Cyanide (Total)	1	140
IP3904	1.00 – 1.10	Yellowish brown silty sandy rounded fine and medium flint and angular and subangular medium and coarse concrete GRAVEL. Rare lengths of timber (up to 300mm long) (Made Ground)	Cyanide (Total)	1	11
			Copper (Bioavailable)	1	28 (1.11)
	1.50 – 1.60		Cyanide (Total)	1	4.6
LWD3801	0.10 – 0.10	Grass over dark brown sandy SILT with rare fragments (up to 100mm) of plastic. Frequent rootlets. (Made Ground)	Cadmium	0.25	0.25
			Copper (Bioavailable)	1	31.00 (1.81)

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	EQS (µg/l)	Result (bioavailable concentration) (µg/l)
WS3401	1.70 – 1.80	Firm brown mottled orangish brown gravelly sandy silty CLAY with occasional pockets up to 30mm diameter of orangish brown clayey silty sand. Gravel is angular to rounded fine to coarse flint and occasional quartzite. (Made Ground)	Lead (Bioavailable)	1.2	5.80 (1.49)
WS3402	0.30 – 0.40	Grass over soft brown and white slightly sandy gravelly silty CLAY. Gravel is angular to subrounded fine and medium chalk, rare brick, tarmac and ceramics. Rare rootlets. (Made Ground)	Lead (Bioavailable)	1.2	6.10 (1.48)

Soil leachate data compared against drinking water standards

5.5.22 The soil leachate exceedances of the DWS guideline values are shown in Table 5.13 below.

5.5.23 There are elevations of selected metals (arsenic; lead; manganese; selenium) and one exceedance of ammoniacal nitrogen. A total of 98 samples out of 148 samples did not record any exceedance of the DWS guideline values.

Table 5.13 Soil leachate samples exceeding the DWS guideline values

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
GI Phase 1					
BH+RC1107	0.10 – 0.30	Vegetation over greyish brown slightly gravelly clayey fine to coarse SAND with frequent fragments (up to 300mm) of black plastic bags. Gravel is subangular and subrounded fine to coarse flint and crystalline rarely chalk. Frequent roots (up to 10mm) and rootlets. (Made Ground)	Manganese	50	110
	1.10 – 1.20	Greyish brown clayey gravelly fine to coarse SAND. Gravel is subangular and subrounded fine to coarse flint and concrete (Made Ground)	Manganese	50	120
BH+RC1109	0.50 – 0.60	Brown becoming light brown slightly clayey, locally clayey sandy locally very sandy angular to subrounded fine to coarse flint, concrete and limestone GRAVEL fragments with rare medium gravel sized fragments of plastic and metal and a low angular concrete cobble content. Frequent roots (up to 5mm diam) and rootlets. (Made Ground)	Lead	10	21
			Manganese	50	100
	1.05 – 1.15		Lead	10	14
			Manganese	50	95
BH+RC1180	0.60 – 0.80	Firm greyish brown slightly sandy slightly gravelly CLAY. Gravel is angular to subrounded fine to coarse chalk rarely flint and brick fragments. (Made Ground)	Ammoniacal Nitrogen (NH_4)	500	533
			Arsenic	10	46

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
CPT1310	0.60 – 0.70	Greenish brown gravelly medium and coarse SAND. Gravel is subangular and subrounded fine to coarse flint. (Made Ground)	Arsenic	10	20
			Lead	10	12
TP1628	1.25 – 1.50	Soft thickly interlaminated brown and orangish brown clayey SILT with frequent thick laminae of black organic clay and frequent pockets (up to 50mm) of orange silt. (Head Deposits)	Manganese	50	230
WS1405	0.40 – 0.45	Dark grey sandy angular and subangular fine to coarse crystalline GRAVEL. (Made Ground)	Arsenic	10	11
WS1423	1.30 – 1.50	Medium dense orangish brown slightly sandy subangular to rounded flint and occasional quartzite GRAVEL. (Glaciofluvial Deposits)	Selenium	10	10
WS1425	0.60 – 0.70	Greenish brown gravelly medium and coarse SAND. Gravel is subangular and subrounded fine to coarse flint. (Glaciofluvial Deposits)	Arsenic	10	14
WS1437b	0.50 – 0.60	Light yellowish brown slightly silty gravelly fine and medium SAND. Gravel is angular and subangular fine to coarse brick, flint and asphalt fragments. (Made Ground)	Manganese	50	70

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
WS1640b	1.80 – 2.00	Stiff grey mottled yellowish brown gravelly sandy silty CLAY. Gravel is subangular to rounded fine and medium chalk, flint and occasional red mudstone fragments. Occasional pockets of grey to brown organic material. (Slight hydrocarbon odour). (Made Ground)	Manganese	50	230
GI Phase 2					
BH+RC1182	0.70 – 0.80	Black to grey sandy subangular and subrounded fine to coarse granite GRAVEL. (Made Ground)	Arsenic	10	13
			Manganese	50	96
BH+RC2204	0.95 – 1.00	Medium dense dark brown slightly silty fine to coarse SAND. (Made Ground)	Manganese	50	110
BH2603	0.20 – 0.30	Brown slightly sandy SILT. (Made Ground)	Ammoniacal Nitrogen (NH_4)	500	836
BH2272	0.20 – 0.30	Dark brown slightly gravelly very sandy SILT. Gravel is angular to subrounded fine to coarse flint, rare brick. (Made Ground)	Manganese	50	390
BH+RC2220	0.90 – 1.10	Medium dense dark brown slightly clayey very gravelly fine to coarse SAND. Gravel is angular to rounded fine to coarse flint and quartzite. (River Terrace Deposits)	Manganese	50	240

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
GI Phase 3					
BH+RC3214	0.00 – 0.20	Soft brown slightly sandy slightly gravelly silty CLAY with abundant rootlets. Gravel is angular to rounded flint, quartzite and chalk. (Made Ground / Reworked Natural Deposits)	Manganese	50	290
BH+RC3221	2.30 – 2.40	Dark grey slightly gravelly SILT with frequent decomposed plant matter up to 20mm long and moderate organic odour. (Alluvium)	Ammoniacal Nitrogen (NH4)	500	2957
			Manganese	50	78
BH3010	0.70 – 0.90	Firm becoming stiff and very stiff brown mottled light grey gravelly silty CLAY. Gravel is angular to rounded fine and medium chalk and rare quartzite and flint. (Lowestoft Formation)	Manganese	50	400
BH3012	0.50 – 0.70	Yellowish brown clayey locally very clayey sandy subangular and subrounded fine to coarse GRAVEL of flint, concrete and chalk. (Made Ground)	Lead	10	24
BH3030	1.00 – 1.20	Firm becoming stiff orangish brown slightly sandy slightly gravelly CLAY with low subangular flint cobble content. Gravel is subangular and subrounded fine to coarse flint and chalk. (Lowestoft Formation)	Manganese	50	220
BH3034	0.60	Firm light brown sandy CLAY. (Alluvium)	Manganese	50	200

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
BH3038	0.10 – 0.20	Crop over soft brown slightly sandy silty CLAY with rare subangular and subrounded fine to coarse brick and flint gravel. (Made Ground)	Manganese	50	270
BH3042	0.20 – 0.30	Crop over soft brown slightly sandy silty CLAY with rare subrounded medium flint gravel. Rare rootlets. (Made Ground / reworked National Deposits)	Manganese	50	280
BH3043	0.10 – 0.30	Grass over soft dark brown slightly sandy slightly gravelly silty CLAY. Gravel is angular to subrounded fine and medium flint and rare quartzite. (Made Ground / reworked National Deposits)	Manganese	50	210
BH3045	0.50 – 0.80	Blackish brown slightly gravelly slightly clayey silty SAND with abundant tile and brick (up to 70mm) and occasional rootlets. Gravel is subangular to rounded fine to coarse flint, sandstone and coal. (Made Ground)	Lead	10	34
BH3046	0.50 – 0.70	Firm orangish brown slightly sandy CLAY with pockets of grey silt and black specks, rare subangular fine to coarse flint gravel. Frequent rootlets. (Lowestoft Formation)	Manganese	50	420
BH3048	0.00 – 0.20	Soft dark brown sandy slightly gravelly CLAY with frequent rootlets. Gravel is subangular fine and medium flint. Occasional plastic bottle fragment and coffee cup lid. (Made Ground)	Lead	10	18

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
BH3054	0.40 – 0.60	Brown clayey sandy subangular and subrounded fine to coarse GRAVEL of flint, concrete and rarely chalk. (Made Ground)	Arsenic	10	12
			Lead	10	11
			Manganese	50	740
IP3901	0.00 – 0.10	Grass over very soft dark brown slightly sandy gravelly CLAY with frequent rootlets. Gravel angular to subrounded fine to coarse red brick, concrete and flint. (Made Ground)	Manganese	50	130
	0.50 – 0.60	Soft dark brown slightly sandy gravelly CLAY. Gravel is subangular and subrounded fine to coarse flint and concrete. (Made Ground)	Arsenic	10	13
			Manganese	50	440
IP3902	1.30 – 1.40	Soft becoming firm orangish brown slightly sandy slightly gravelly silty CLAY with frequent becoming rare rootlets. Gravel is subangular to rounded fine to coarse flint and quartzite. 0.45m: White 80mm diameter plastic pipe. 1.30 - 1.60m: Black. Strong hydrocarbon odour. (Made Ground)	Manganese	50	140
IP3904	1.50 – 1.60	Yellowish brown silty sandy rounded fine and medium flint and angular and subangular medium and coarse concrete GRAVEL. Rare lengths of timber (up to 300mm long) 1.50m: Gravel is greyish brown with rare black staining up to 35mm. Faint hydrocarbon odour. Thin oil slick on seeping groundwater. (Made Ground)	Arsenic	10	13

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
LWD3801	0.10 – 0.10	Grass over dark brown sandy SILT with rare fragments (up to 100mm) of plastic. Frequent rootlets. (Made Ground)	Lead	10	25
TP3529	0.00 – 0.20	Grass over very soft dark brown slightly sandy slightly gravelly silty CLAY with frequent rootlets. Gravel is subangular and subrounded fine to coarse flint and red brick. (Made Ground)	Manganese	50	250
TP3537	0.00 – 0.20	Grass over soft brown slightly sandy slightly gravelly silty CLAY with frequent rootlets. Gravel is subangular and subrounded fine to coarse flint. (Made Ground / Reworked Natural Deposits)	Manganese	50	270
TP3543	0.00 – 0.20	Grass over very soft brown slightly sandy slightly gravelly silty CLAY with frequent rootlets. Gravel is subangular and subrounded fine to coarse flint and red brick. (Made Ground)	Manganese	50	280
TP3545	0.60 – 0.70	Soft becoming firm dark brown slightly gravelly slightly sandy silty CLAY with low brick cobble content and frequent rootlets. Gravel is subangular and subrounded fine to coarse porcelain, coal, flint, brick and quartz. (Made Ground)	Benzo(a)pyrene	0.01	0.01

Location ID	Depth range (mbgl)	Description (geological formation)	Exceeding analytes	DWS (µg/l)	Result (µg/l)
WS3418	0.50 – 0.70	Soft orangish brown slightly gravelly slightly sandy silty CLAY with occasional rootlets. Gravel is subangular to rounded fine to coarse flint and chalk (Lowestoft Formation)	Manganese	50	170
WS3420	0.50 – 0.70	Soft orangish brown with dark brown/black staining slightly gravelly slightly sandy silty CLAY. Gravel is angular to rounded fine to coarse flint, chalk and quartzite. (Lowestoft Formation)	Manganese	50	300
WS3425	0.50 – 0.70	Soft becoming firm orangish dark brown slightly gravelly slightly sandy silty CLAY. Gravel is angular to rounded fine to coarse flint, chalk and quartzite. (Lowestoft Formation)	Manganese	50	300
WS3427	0.00 – 0.20	Soft brown slightly gravelly slightly sandy silty CLAY with abundant rootlets. Gravel is angular to rounded fine to coarse flint and quartzite. (Made Ground / Reworked Natural Deposits)	Manganese	50	250
WS3431	0.50 – 0.70	Soft orangish brown slightly gravelly sandy silty CLAY. Gravel is subangular to rounded fine to coarse chalk and flint. (Lowestoft Formation)	Manganese	50	460
WS3436	0.50 – 0.70	Firm orangish brown slightly sandy gravelly silty CLAY. Gravel is angular to rounded fine to coarse flint and chalk. (Interglacial Deposits)	Manganese	50	220

Waste soil assessment

5.5.24 Current regulations require that the disposal of construction waste to landfill is minimised. Where possible, excavated soils from construction of the proposed scheme are anticipated to be re-used on the proposed scheme if geotechnically and environmentally suitable. Unsuitable soils may require disposal. A waste soil assessment has been undertaken and consists of a preliminary waste classification and landfill Waste Acceptance Criteria (WAC) testing of the soils as an example, should any material be disposed of to landfill. Samples of actual materials to be disposed of must be tested.

Preliminary waste classification

5.5.25 A preliminary waste classification has been undertaken for all the 381 soil results using HazWaste Online, a programme which enables waste characterisation of soil based on chemical analysis in accordance with the Environment Agency guidance, 'Hazardous Waste: Interpretation of the definition and classification of hazardous waste, Technical Guidance WM3' (2015). This assessment classifies each sample as either "Hazardous" (European Waste Catalogue (EWC) Code 17-05-03) or "Non-Hazardous" (EWC Code 17-05-04).

5.5.26 HazWaste Online draws its results from an algorithmic model that is based on a number of conservative assumptions.

5.5.27 Based on the assessment, the majority of the soils tested as part of the ground investigation would be classed as non-hazardous material. The eight samples that classified as hazardous material are summarised in Table 5.14 below and shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].

Table 5.14 Soil samples exceeding the WM3 hazardous waste guideline values

Location ID	Depth range (mbgl)	Description (geological formation)	Hazardous determinand	Result (mg/kg)	Location relative to the proposed scheme	Proposed earthworks at location
GI Phase 1						
BH+RC1106	0.90 – 1.00	Brown slightly gravelly silty fine to coarse SAND. Gravel is angular to subrounded flints. (Glaciofluvial Deposits)	TPH (C6 – C40)	3880	Station Road, Hatfield Peverel	Material unlikely to be excavated at this location, other than to tie in new pavement layers.

Location ID	Depth range (mbgl)	Description (geological formation)	Hazardous determinand	Result (mg/kg)	Location relative to the proposed scheme	Proposed earthworks at location
BH+RC1178	3.20 – 3.40	Stiff locally very stiff grey slightly sandy gravelly silty CLAY. Gravel is subangular to rounded flint, brick, concrete, glass and ceramic tile. Occasional carbonaceous traces including charcoal. (Made Ground)	Lead (Lead compound with the exception to those specified in HazWaste annex – worst case)	1600	Westbound on-slip road, junction 19	Low strength Made Ground may be excavated as part of the proposed realignment at junction 19.
			Zinc (Zinc oxide)	4800		
WS1402	0.20 – 0.40	Yellowish brown very sandy subangular to rounded fine to coarse flint GRAVEL. (Made Ground)	TPH (C6 – C40)	1230	Eastbound Carriageway, junction 19	No widening of the mainline proposed at this location
WS1435B	0.50 – 0.80	Dark brown sandy gravelly SILT with occasional rootlets and rare flint and tarmac cobbles (up to 80mm). Gravel is subangular and subrounded fine to coarse flint, quartzite, tarmac and brick. (Made Ground)	TPH (C6 – C40)	1435	Westbound Carriageway, south of Witham	Proposed embankment widening at this location. Materials may be removed and replaced beneath the proposed earthwork footprint.

Location ID	Depth range (mbgl)	Description (geological formation)	Hazardous determinand	Result (mg/kg)	Location relative to the proposed scheme	Proposed earthworks at location
WS1437B	0.20 – 0.30	Soft brown slightly sandy gravelly CLAY. Gravel is angular to subrounded dine to coarse brick, flint and asphalt. (Made Ground)	TPH (C6 – C40)	2160	Westbound Carriageway, south-east of Witham	Proposed embankment widening at this location. Materials may be removed and replaced beneath the proposed earthwork footprint.
	0.50 – 0.60	Light yellowish brown slightly silty gravelly fine and medium SAND. Gravel is angular and subangular fine to coarse brick, flint and asphalt. (Made Ground)	TPH (C6 – C40)	1240		
GI Phase 2						
BH+RC2201A	0.45 – 0.55	Light brown very sandy subangular fine to coarse flint, asphalt and concrete GRAVEL. (Made Ground)	TPH (C6 – C40)	2130	Westbound Carriageway, south-east of Witham	Bridge abutment to be widened at location. Removal of material may be required.

Location ID	Depth range (mbgl)	Description (geological formation)	Hazardous determinand	Result (mg/kg)	Location relative to the proposed scheme	Proposed earthworks at location
GI Phase 3						
BH3024	2.80 – 2.90	Asphalt (~25mm) over slightly sandy GRAVEL with low subrounded concrete cobble content. Gravel is multi-coloured angular to subrounded fine to coarse flint, concrete and black probable asphalt. (Made Ground)	TPH (C6 – C40)	1168	Eastbound Carriageway, junction 24	Proposed cutting widening at this location. Materials may be removed beneath the proposed earthwork footprint.
BH3045	0.50 – 0.80	Blackish brown slightly gravelly slightly clayey silty SAND with abundant tile and brick (up to 70mm) and occasional rootlets. Gravel is subangular to rounded fine to coarse flint, sandstone and coal. (Made Ground)	Asbestos	1660	Old London Road; side road near junction 25	Replacement of existing side road. Material may need to be removed from area to tie into the existing pavement.

Waste acceptance criteria (WAC) assessment

5.5.28 Once a waste soil is classified into non-hazardous or hazardous, Landfill Waste Acceptance Criteria (WAC) testing is used. In the case of hazardous wastes, this is to determine if the waste soil can go to a stable non-reactive hazardous landfill, a hazardous waste landfill, or whether further treatment is required prior to disposal. In the case of non-hazardous wastes, no WAC test is required ahead of disposal to non-hazardous landfill. However, WAC tests can be used to determine if a non-hazardous soil is likely to be considered inert, although this also depends on the composition of the soil (i.e. whether natural or containing significant anthropogenic debris).

Asphalt assessment

5.5.29 Historical pavements were found under certain areas of the A12 highway. Given the potential age of the pavements there is potential they may contain coal tar which was commonly used in road construction until the mid-1980s. Coal tar includes a mixture of hydrocarbons which are carcinogenic and highly toxic. An assessment of two samples of the historical pavement has been undertaken to determine potential risk to the environment and human health. A waste assessment has also been completed.

Asphalt solids assessment

5.5.30 A total of two samples of asphalt were tested for the general soil suite (Suite E1) described in Table 4.4.

5.5.31 No asbestos containing material or free asbestos fibres were identified.

5.5.32 All concentrations of inorganics, metals, semi-metalloids, TPH (inc. BTEX), PCBs, VOC and SVOC were recorded below the generic screening criteria for soils.

5.5.33 There are some exceedances for speciated PAH - these are summarised in Table 5.15 below.

Table 5.15 Asphalt samples exceeding the commercial/industrial guideline values

Location ID	Depth range (mbgl)	Description (geological formation)	Speciated PAH	Commercial / industrial S4UL (mg/kg)	Result (mg/kg)
BH+RC1106	0.40 – 0.50	Asphalt with a strong hydrocarbon odour (Made Ground)	Benzo(b)fluoranthene	44	58
			Benzo(a)pyrene	35	52
			Dibenz(a,h)anthracene	3.5	5.5
WS1429A	0.82 – 0.92	Black asphalt (Made Ground)	Benzo(a)anthracene	170	270
			Benzo(b)fluoranthene	44	190
			Benzo(a)pyrene	35	200
			Dibenz(a,h)anthracene	3.5	25

Asphalt waste assessment

5.5.34 The WM3 assessment using HazWaste Online classified the material as hazardous waste. The one tarmac sample analysed for WAC testing indicated it was suitable for stable non-reactive hazardous disposal. This is summarised in Table 5.16 below.

Table 5.16 Asphalt WAC sample compared against WM3 assessment

Location ID	Depth range (mbgl)	Description (geological formation)	WM3 assessment	WAC assessment
BH+RC1106	0.40 – 0.50	Asphalt with strong hydrocarbon odour. (Made Ground)	Hazardous	WAC not scheduled
WS1429A	0.82 – 0.92	Black Asphalt (Made Ground)	Hazardous	Stable Non-Reactive Hazardous

Groundwater quality assessment

5.5.35 Samples of groundwater were taken from selected locations and tested for chemical concentrations to assess groundwater quality within the superficial aquifers underlying the proposed scheme.

5.5.36 As specified, three rounds of groundwater monitoring were completed at each standpipe. Due to a number of the standpipes being dry or having insufficient water to sample, this meant that it was not possible to get three samples from every location. One location, BH+RC1114 was sampled four times.

5.5.37 A total of 136 samples of groundwater were tested for the general groundwater suite (Suite F1) which included analysis of inorganics, metals, semi-metalloids, TPH and PAH. A total of 52 samples were additionally analysed for the expanded Suite F2 which include VOC and SVOC. A further 45 samples were analysed for expanded Suite F3 which includes Aromatic and Aliphatic banded TPH analysis including BTEX.

5.5.38 The results were compared against the relevant screening criteria for controlled waters risk assessment EQS (annual average) to assess the risk to controlled water receptors in close proximity to the proposed scheme. Screening against the DWS has been undertaken only on locations that are located within a source protection zone.

5.5.39 Most concentrations of TPH (including BTEX), PCBs, VOC and SVOC were recorded below the laboratory limit of detection. Trace concentrations of a number of VOCs and SVOC were detected in boreholes BH+RC1109, BH2674, BH+RC2201, BH+RC3206 however there are no exceedances of the EQS. BH+RC1178, BH2674, BH+RC2201, BH+RC3206 and WS3408 recorded TPH in one monitoring round, TPH was also identified in BH2676 in two rounds. However, concentrations of TPH in BH+RC3206 and WS3408 exceed the DWS.

5.5.40 There are widespread elevations of a range of general inorganic chemicals (cyanide, chloride, sulphate, ammoniacal nitrogen, nitrite, nitrate). A total of 68 samples out of 136 samples recorded no exceedance of the EQS for the general inorganic analytes.

5.5.41 There are some elevated results of metals and semi-metals (cadmium; copper; lead; manganese; nickel; zinc). A total of 100 samples out of 136 samples

recorded no exceedance of any metal or semi-metal. The majority of the exceedances were only recorded in one monitoring round.

5.5.42 The exceedances of the relevant screening criteria for controlled waters recorded from the sampling rounds are detailed in Table 5.17 (EQS exceedances) and Table 5.18 (DWS exceedances) below. It should be noted that the Environment Agency's Remedial Targets Methodology guidance allow a risk-based and a cost-benefit approach to be applied to groundwater contamination. Exceedance of a target concentration does not necessarily imply that an unacceptable risk exists or that remediation is required.

Table 5.17 Groundwater exceedances of the EQS

Location ID	Exceeding analyte	Exceeding rounds / total rounds	EQS (µg/l)	Results *(Bioavailable concentration)* (µg/l)
GI Phase 1				
BH+RC1101	Cadmium	3 / 3	0.25	5.7; 0.35; 0.29
	Chloride	3 / 3	250,000	370,000; 250,000; 290,000
	Copper	1 / 3	1 (*Bioavailable*)	61 (*2.35*)
	Lead	1 / 3	1.2 (*Bioavailable*)	87 *(15.32)*
	Manganese	2 / 3	123 (*Bioavailable*)	2,600 (*310*); 1,400 (*246*)
	Nickel	3 / 3	4 (*Bioavailable*)	77 (*15*); 83 (*17*); 53 (*11*)
	Zinc	1 / 3	10.9 (*Bioavailable*)	89 (*35*)
BH+RC1104	Cadmium	1 / 3	0.25	1.5
	Lead	1 / 3	1.2 (*Bioavailable*)	79 *(11.63)*
	Nickel	1 / 3	4 (*Bioavailable*)	77 (*16*)
	Sulphate	3 / 3	400,000	3,400,000; 2,130,000; 3,200,000
	Zinc	1 / 3	10.9 (*Bioavailable*)	120 (*52*)
BH+RC1107	Manganese	1 / 3	123 (*Bioavailable*)	350 (*298*)
BH+RC1108	Copper	1 / 3	1 (*Bioavailable*)	9.1 (*1.18*)
	Cyanide (Total)	1 / 3	1	1.6

Location ID	Exceeding analyte	Exceeding rounds / total rounds	EQS (µg/l)	Results *(Bioavailable concentration)* (µg/l)
BH+RC1109	Copper	1 / 3	1 (*Bioavailable*)	57 (*7.62*)
BH+RC1114	Copper	1 / 4	1 (*Bioavailable*)	12 (*1.43*)
	Chloride	4 / 4	250,000	320,000; 310,000; 330,000; 310,000
	Cyanide (Total)	2 / 4	1	1.3; 3
BH+RC1160a	Chloride	3 / 3	250,000	920,000; 960,000; 800,000
	Cyanide (Total)	1 / 3	1	6.9
	Manganese	2 / 3	123 (*Bioavailable*)	1,800 (*215*) 1,300 (*128*)
BH+RC1164a	Chloride	2 / 3	250,000	370,000; 250,000
	Cyanide (Total)	1 / 3	1	1.8
	Manganese	1 / 3	123 (*Bioavailable*)	490 (*127*)
BH+RC1166a	Chloride	2 / 2	250,000	370,000; 370,000
	Manganese	2 / 2	123 (*Bioavailable*)	2,600 (*275*) 2,700 (*575*)
BH+RC1177a	Chloride	3 / 3	250,000	310,000; 360,000; 380,000
	Cyanide (Total)	1 / 3	1	1.5
BH+RC1178	Cyanide (Total)	2 / 3	1	1.5; 3.5
BH+RC1181	Copper	1 / 2	1 (*Bioavailable*)	7.9 (*1.01*)
	Manganese	1 / 2	123 (*Bioavailable*)	3,000 (*433*)
WS1403	Cyanide (Total)	1 / 3	1	1.8
WS1523	Cyanide (Total)	1 / 3	1	4
GI Phase 2				
BH2674	Cadmium	1 / 3	0.25	0.36

Location ID	Exceeding analyte	Exceeding rounds / total rounds	EQS (µg/l)	Results *(Bioavailable concentration)* (µg/l)
	Chloride	2 / 3	250,000	290,000; 280,000
	Fluoranthene	1 / 3	0.0063	0.24
	Lead	1 / 3	1.2 (*Bioavailable*)	150 *(13.04)*
	Manganese	2 / 3	123 (*Bioavailable*)	1300 *(188)*; 1200 *(173)*
	Sulphate (SO_4)	2 / 3	400,000	458,000; 626,000
BH+RC2201	Cadmium	1 / 3	0.25	0.77
	Chloride	2 / 3	250,000	250,000; 260,000
	Chromium (III)	1 / 3	4.7	9.3
	Copper	1 / 3	1 (*Bioavailable*)	36 *(1.6)*
	Lead	2 / 3	1.2 (*Bioavailable*)	150 *(7.5)*; 87 *(12.4)*
	Manganese	3 / 3	123 (*Bioavailable*)	500 *(500)*; 980 *(980)*; 400 *(185)*
	Nickel	2 / 3	4 (*Bioavailable*)	25 *(4.6)*; 14 *(4.5)*
BH2676	Chloride	2 / 3	250,000	290,000; 430,000
	Manganese	3 / 3	123	761; 465; 775
GI Phase 3				
BH+RC3202	Copper	1 / 3	1 (*Bioavailable*)	5.50 *(1.53)*
	Manganese	2 / 3	123 (*Bioavailable*)	670 *(309)*; 2900 *(749)*
	Nickel	1 / 3	4 (*Bioavailable*)	7.40 *(4.18)*
BH+RC3204	Cyanide (Total)	1 / 3	1	2.60
	Manganese	1 / 3	123 (*Bioavailable*)	1400 *(533)*
BH+RC3206	Cyanide (Total)	1 / 3	1	9.80

Location ID	Exceeding analyte	Exceeding rounds / total rounds	EQS (µg/l)	Results *(Bioavailable concentration)* (µg/l)
	Chloride	3 / 3	250,000	260,000; 660,000; 630,000
	Anthracene	2 / 3	0.1	1.06; 0.21
	Fluoranthene	2 / 3	0.0063	6.54; 0.53
	Benzo(b)fluoranthene	1 / 3	0.00017	3.64
	Benzo(k)fluoranthene	1 / 3	0.00017	1.43
	Benzo(a)pyrene	1 / 3	0.00017	3.01
	Indeno(1,2,3-cd)pyrene	1 / 3	0.00017	1.66
	Benzo(ghi)perylene	1 / 3	0.00017	1.98
	Chromium (III)	2 / 3	4.7	5.8; 6.2
	Manganese	3 / 3	123 (*Bioavailable*)	1100 *(131)*; 2900 *(345)*; 3100 *(304)*
BH+RC3209	Chromium (III)	1 / 3	4.7	5.0
	Manganese	3 / 3	123 (*Bioavailable*)	1500 *(305)*; 1300 *(306)*; 1200 *(307)*
BH3011	Chloride	2 / 3	250,000	290,000; 310,000
	Copper	1 / 3	1 (*Bioavailable*)	13 (*1.04)*
BH3015	Chromium (III)	1 / 3	4.7	6.0
BH3050	Cyanide (Total)	1 / 3	1	2.0
BH3051	Cyanide (Total)	1 / 3	1	8.5
BH3052	Cyanide (Total)	1 / 3	1	7.7
BH3053	Chromium (III)	1 / 3	4.7	5.2
BH3054	Chloride	3 / 3	250,000	830,000; 650,000; 730,000
	Manganese	1 / 3	123 (*Bioavailable*)	1300 *(128)*

Location ID	Exceeding analyte	Exceeding rounds / total rounds	EQS (µg/l)	Results *(Bioavailable concentration)* (µg/l)
WS3402G	Cyanide (Total)	1 / 3	1	7.3
	Sulphate	3 / 3	400,000	946,000; 954,000; 653,000
WS3406	Chromium (III)	1 / 3	4.7	8.5
WS3408	Cyanide (Total)	1 / 3	1	5.4
	Fluoranthene	1 / 3	0.0063	0.41
WS3432	Cyanide (Total)	1 / 3	1	3.4
	Sulphate	1 / 3	400,000	450,000
	Chloride	3 / 3	250,000	330,000; 370,000; 370,000

Table 5.18 Groundwater exceedances of the DWS

Location ID	Exceeding analyte	Exceeding rounds / total rounds	DWS (µg/l)	Results (µg/l)
GI Phase 1	Samples were not screened against DWS as no SPZ present			
GI Phase 2				
GI Phase 3				
BH+RC3202	Nitrate (as NO_3)	2 / 3	50,000	84,000; 112,000
	Nitrite (as NO_2)	1 / 3	500	887
	Manganese	3 / 3	50	670; 2,900; 340
BH+RC3204	Nitrate (as NO_3)	2 / 3	50,000	96,000; 99,000
	Nitrite (as NO_2)	1 / 3	500	9,200
	Manganese	3 / 3	50	1,400,000; 630,000; 180,000
BH+RC3205	Manganese	3 / 3	50	820,000; 330,000; 370,000
BH+RC3206	Electrical Conductivity at 20 °C	2 / 3	2500*	2,600*; 2,700*

Location ID	Exceeding analyte	Exceeding rounds / total rounds	DWS (µg/l)	Results (µg/l)
	Chloride	3 / 3	250,000	260,000; 660,000; 630,000
	Benzo(b)fluoranthene	1 / 3	0.1	3.64
	Benzo(k)fluoranthene	1 / 3	0.1	1.43
	Benzo(a)pyrene	1 / 3	0.01	3.01
	Indeno(1,2,3-cd)pyrene	1 / 3	0.1	1.66
	Benzo(ghi)perylene	1 / 3	0.1	1.98
	Manganese	3 / 3	50	1,100; 2,900; 3,100
	TPH (C6 – C40)	1 / 3	10	13,000
BH+RC3209	Manganese	3 / 3	50	1,500; 1,300; 1,200
BH+RC3216	Manganese	1 / 3	50	87
BH+RC3218	Sulphate (as SO_4)	1 / 3	250,000	267,000
	Ammoniacal Nitrogen (as NH_4)	1 / 3	500	520
	Nitrite (as NO_2)	1 / 3	500	1,051
	Manganese	3 / 3	50	520; 160; 230
BH3011	Chloride	2 / 3	250,000	290,000; 310,000
	Nitrate (as NO_3)	3 / 3	50,000	8,200; 8,700; 9,800
	Nitrite (as NO_2)	1 / 3	500	887
	Manganese	3 / 3	50	89; 97; 81
BH3015	Nitrate (as NO_3)	2 / 3	50,000	5,600; 6,900
BH3025	Nitrate (as NO_3)	1 / 3	50,000	5,400
	Manganese	2 / 3	50	890; 150
BH3027	Nitrate (as NO_3)	1 / 3	50,000	97,000
BH3035	Manganese	3 / 3	50	220; 120; 150
BH3051	Nitrite (as NO_2)	1 / 3	500	1643
	Manganese	3 / 3	50	420; 260; 150

Location ID	Exceeding analyte	Exceeding rounds / total rounds	DWS (µg/l)	Results (µg/l)
BH3052	Manganese	2 / 3	50	440; 250
BH3053	Ammoniacal Nitrogen (as NH_4)	1 / 3	500	3,471
	Nitrate (as NO_3)	1 / 3	50,000	50,000
BH3054	Electrical Conductivity at 20 °C	1 / 3	2500*	2,500*
	Chloride	3 / 3	250,000	830,000; 650,000; 730,000
	Ammoniacal Nitrogen (as NH_4)	2 / 3	500	850; 780
	Manganese	3 / 3	50	840; 640; 1,300
WS3402G	Electrical Conductivity at 20 °C	1 / 3	2500*	2,500*
	Sulphate (as SO_4)	3 / 3	250,000	946,000; 954,000; 653,000
	Manganese	3 / 3	50	380; 420; 410
WS3406	Sulphate (as SO_4)	3 / 3	250,000	263,000
	Nitrite (as NO_2)	3 / 3	500	1,511; 1,544; 986
	Manganese	1 / 3	50	70
WS3408	Sulphate (as SO_4)	3 / 3	250,000	277,000
	Nitrite (as NO_2)	3 / 3	500	2,103; 7,229
	Manganese	2 / 3	50	650; 180
	TPH (C6 – C40)	1 / 3	10	4,600
WS3409	Nitrite (as NO_2)	1 / 3	500	1,084
	Manganese	3 / 3	50	710; 740; 280
WS3419	Nitrite (as NO_2)	2 / 3	500	2,826; 4,929
	Manganese	1 / 3	50	110
WS3426	Nitrate (as NO_3)	2 / 3	50,000	50,000; 65,000
	Nitrite (as NO_2)	2 / 3	500	3,286
WS3432	Sulphate (as SO_4)	3 / 3	250,000	405,000; 348,000; 346,000

Location ID	Exceeding analyte	Exceeding rounds / total rounds	DWS (µg/l)	Results (µg/l)
	Chloride	3 / 3	250,000	330,000; 370,000; 370,000
	Nitrate (as NO_3)	3 / 3	50,000	193,000; 214,000; 197,000
	Nitrite (as NO_2)	3 / 3	500	3,614; 2,826; 2,399
	Manganese	2 / 3	50	95; 76
* Electrical conductivity measured in µS/cm				

Ground gas assessment

5.5.43 Ground gas monitoring was undertaken from selected locations across the proposed scheme to evaluate the risk of ground gases to construction workers. A summary of the boreholes monitored are presented in Table 5.19 below.

5.5.44 As specified, six rounds of ground gas monitoring were completed at each standpipe. Some locations received fewer than six rounds of monitoring due to access issues, however this is not thought to affect the assessment overall.

5.5.45 Ground gas monitoring was undertaken during both rising and falling atmospheric conditions to record any effects this may have on the results.

5.5.46 Generally, the Made Ground and superficial deposits underlying the proposed scheme generate low concentrations of gas and flow rates. BH+RC2676 and BH+RC3206 were found to be hypoxic all monitoring rounds. This may be caused by the Witham sewage treatment works adjacent to the west and thickness of made ground respectively.

5.5.47 The results of the ground gas analysis shown in Table 5.19 below.

Table 5.19 Ground Gas Assessment

Location ID	Maximum flow rates (l/hour)		Max. methane (%)	Max. carbon dioxide (%)	Max oxygen (%)	Max carbon monoxide (ppm)	Max hydrogen sulphide (ppm)	Max VOC (ppm)
	Negative	Positive						
GI Phase 1								
BH1001	0.0	0.0	0.0	0.0	19.2	10	0.0	0.0
BH+RC1104	0.0	23.4	0.0	2.3	20.1	0	0.0	42.5
BH+RC1106	0.0	0.0	0.0	1.7	20.2	10	0.0	30.2
BH+RC1109	-2.4	0.0	0.0	2.6	18.5	495	0.0	13.6
BH+RC1114	-3.0	0.0	0.2	2.7	15.6	10	0.0	2.8

Location ID	Maximum flow rates (l/hour)		Max. methane (%)	Max. carbon dioxide (%)	Max oxygen (%)	Max carbon monoxide (ppm)	Max hydrogen sulphide (ppm)	Max VOC (ppm)
	Negative	Positive						
BH+RC1166	-12.0	0.0	0.0	6.8	19.9	10	16.6	1.1
BH+RC1177a	0.0	0.0	0.0	6.3	11.9	17	0.0	3.2
BH+RC1178	0.0	0.0	0.2	9.3	15.6	0	0.0	25.5
BH+RC1181	-1.8	0.0	2.7	5.5	11.1	35	0.0	13.6
WS1422	0.0	0.0	0.0	1.6	20.5	0	0.0	0.7
WS1432	0.0	0.0	0.0	4.7	19.5	0	0.0	12.8
WS1437B	-1.2	0.0	0.0	2.2	19.4	10	0.0	0.7
WS1523	0.0	0.0	0.2	1.8	20.8	0	0.0	50
GI Phase 2								
BH+RC2201 - Shallow	-71.8	0.0	0.0	0.0	20.7	11	0.0	29.4
BH+RC2201 – Deep	0.0	121.5	0.0	2.0	20.4	0	0.0	4.2
BH+RC2676	0.0	0.0	0.0	4.2	18.6	0	0.0	18.6
BH2625	-7.8	0.0	0.0	3.3	20.2	0	0.0	44.0
BH2674	-0.2	3.5	1.0	7.1	17.2	10	0.0	16.6
GI Phase 3								
BH3025	0.0	30.0	0.0	1.5	20.0	34.0	0.0	1.5
BH3049A	-3.2	15	0.0	5.2	20.9	0.0	0.0	1.2
BH3050	-5.5	2.7	0.0	7.1	13.5	0.0.	0.0	1.0
BH3051 – Shallow	0.0	1.3	0.0	4.3	14.1	0.0	0.0	0.5
BH3051 – Deep	0.0	0.0	0.0	3.	17.8	0.0	0.0	0.1
BH3052	0.0	0.0	0.0	2.7	20.7	0.0	0.0	0.5
BH3053	-14.0	23.0	0.0	3.3	20.6	0.0	0.0	0.1
BH+RC3206 – Shallow	0.0	2.8	0.0	1.5	19.8	25.0	0.0	1.6
BH+RC3206 – Deep	0.0	0.7	0.0	2.4	1.8	10.0	0.0	10.0

Location ID	Maximum flow rates (l/hour)		Max. methane (%)	Max. carbon dioxide (%)	Max oxygen (%)	Max carbon monoxide (ppm)	Max hydrogen sulphide (ppm)	Max VOC (ppm)
	Negative	Positive						
BH+RC3218	-4.5	1.2	0.0	2.8	20.2	0.0	0.0	0.2
WS3436	-3.0	0.0	0.0	3.2	20.1	0.0	0.0	0.3

Revised conceptual site model and risk assessment

5.5.48 The CSM and preliminary risk assessment have been re-evaluated given the ground investigation and the assessment undertaken in this report. This is based on the initial CSM developed during the early stage of the scheme design.

5.5.49 The assessment in Table 5.20 is based on the guidance given in Environment Agency's LCRM guidance.

Table 5.20 Updated conceptual site model

Potential sources	Potential receptors (R)	Potential pathways (P)	Comment
Human health			
Made Ground **Existing A12 Road Construction (S5d)** Exceedances of Benzo(b)fluoranthene, Benzo(a)pyrene, benzene, naphthalene, Dibenzo(a,h)anthracene and asbestos containing materials in 5 No. soil and 2 No. tarmac samples. Carbon dioxide and carbon monoxide ground gas.	Construction workers **(R1a)**	Direct contact, dermal absorption, and inhalation **(P1)**	Only a small number of soil samples have exceeded the human health guideline values; therefore, it is reasonable to assume a low likelihood of encountering similar material during construction. Historical road surfaces have been identified underneath the existing A12 that contain elevated levels of PAHs that exceed the human health guidelines. Similar materials could be encountered elsewhere where existing pavements or buried historical pavements are excavated.
		Inhalation of hazardous gases or fuel vapours lead to asphyxiation **(P3)**	The gas risk assessment undertaken shows that the majority of the proposed scheme has very low gas generating potential. The ground investigation has shown the pollution linkage is not considered likely to exist.
	Future maintenance workers **(R1b)**	Direct contact, dermal absorption, and inhalation **(P1)**	Only a small number of samples have exceeded the human health guideline values; therefore, it is reasonable to assume a low likelihood of encountering similar material during future maintenance.
	Future site users (operational phase) **(R1c)**	Direct contact, dermal absorption, and inhalation **(P1)**	It is unlikely that exposed soils would be present as part of the proposed scheme, therefore direct contact is unlikely. The pollution linkage is not considered likely to exist.
	Nearby residential and commercial properties **(R1d)**	Inhalation of wind- blown soil dust **(P2)**	There is a low likelihood of fugitive dust impact near site users due to the likely dispersal of any contaminants during air mixing.

Potential sources	Potential receptors (R)	Potential pathways (P)	Comment
Contaminants in the Groundwater Widespread exceedances of general inorganic analytes and metals / semi-metals in the secondary aquifers underlying the proposed scheme.	Construction workers **(R1a)**	Direct contact and dermal absorption **(P1)**	There is limited potential for construction workers to come in direct contact with potentially contaminated groundwater.
	Future maintenance workers **(R1b)**	Direct contact and dermal absorption **(P1)**	There is limited potential for maintenance workers to come in direct contact with potentially contaminated groundwater.
Controlled waters			
Made Ground **Existing A12 Road Construction (S5d)** Existing A12 Carriageway **(S5d)** Leachate testing exceedances for various metals and PAHs.	Secondary A, B and Secondary Undifferentiated aquifers within the superficial deposits beneath the proposed scheme. **(R2a [1])**	Leaching of contaminants from soil to groundwater **(P4)**	There were exceedances of the leachate generic assessment criteria thresholds. Leaching of the contaminants to the underlying superficial aquifers during excavation, transport and storage is theoretically possible.
		Vertical and lateral migration in groundwater **(P5)**	
		Surface run-off of contaminants including from stockpiled soils **(P6)**	
	Licensed groundwater abstractions located within proximity to the proposed scheme **(R2c)**	Leaching of contaminants from soil to groundwater **(P4)**	There were exceedances of the leachate generic assessment criteria thresholds. Leaching of the contaminants to the underlying superficial aquifers is theoretically possible. However, the proximity of the abstractions is generally over 100m from the proposed scheme and so it is unlikely they would be affected.
		Vertical and lateral migration in groundwater **(P5)**	
		Surface run-off of contaminants including from stockpiled soils **(P6)**	

Potential sources	Potential receptors (R)	Potential pathways (P)	Comment
	Surface waters near the proposed scheme including, River Ter, River Brain, River Blackwater, River Chelmer and their tributaries **(R3a)**	Runoff of via drainage channels **(P7)**	Leaching of the contaminants and subsequent transportation via drainage channels is theoretically possible.
		Direct runoff to surface waters **(P8)**	Leaching of the contaminants to then be transported via direct runoff is unlikely given the relative distances to the surface water bodies.
		Migration to surface water via groundwater pathway (baseflow) **(P9)**	Leaching of the contaminants to then be transported via groundwater is unlikely given the relative distances to the surface water bodies.
	Surface water abstractions located within 250m of the proposed scheme **(R3b)**	Runoff of via drainage channels **(P7)**	The surface water abstractions within 250m of the proposed scheme are all up hydraulic gradient, so it is unlikely they would be affected by any leachable contaminants.
		Direct runoff to surface waters **(P8)**	
		Migration to surface water via groundwater pathway (baseflow) **(P9)**	
Contaminants in the Groundwater Widespread exceedances of general inorganic analytes and metals / semi-metals in the secondary aquifers underlying the scheme for protection of aquatic environment.	Secondary A, B and Secondary Undifferentiated aquifers within the superficial deposits beneath the proposed scheme. **(R2a [1])**	Vertical and lateral migration in groundwater **(P5)**	Mitigation from diffusion and dilution prior to reaching sensitive receptors.
	Licensed groundwater abstractions located within proximity to the	Vertical and lateral migration in groundwater **(P5)**	The groundwater in the superficial deposits underlying the proposed scheme have been found to have widespread elevated levels of contaminants. The potential for this contamination to spread to other areas

Potential sources	Potential receptors (R)	Potential pathways (P)	Comment
	proposed scheme **(R2c)**		is unknown, but it is assumed that given the age of the deposits the groundwater has mostly homogenized.
	Surface waters within near the proposed scheme including, River Ter, River Brain, River Blackwater, River Chelmer and their tributaries **(R3a)**	Vertical and lateral migration in groundwater **(P5)**	The groundwater in the superficial deposits underlying the proposed scheme have been found to have widespread elevated levels of contaminants. The groundwater may be in hydraulic continuity with surface water features and may migrate to surface water.
		Runoff of via drainage channels **(P7)**	The groundwater in the superficial deposits underlying the proposed scheme have been found to have elevated levels of contaminants. For design section 1 (junction 19 to 21) and design section 2 (junction 21 to 23) groundwater is unlikely to be encountered in substantial quantities during construction to require dewatering and thus the risk via runoff is unlikely. For design section 3 (junction 23 to 25) some excavations may require dewatering. Appropriate working practices and mitigation measures to prevent risks to controlled waters should be followed.
	Surface water abstractions located within 250m of the proposed scheme **(R3b)**	Runoff of via drainage channels **(P7)**	The groundwater in the superficial deposits underlying the proposed scheme have been found to have elevated levels of contaminants. For design section 1 (junction 19 to 21) and design section 2 (junction 21 to 23) groundwater is unlikely to be encountered in substantial quantities during construction to require dewatering and thus the risk via runoff is unlikely. For design section 3 (junction 23 to 25) some excavations may require dewatering. Appropriate working practices and mitigation measures to prevent risks to controlled waters should be followed.

Potential sources	Potential receptors (R)	Potential pathways (P)	Comment
			Furthermore, the surface water abstractions within 250m of the proposed scheme are all up hydraulic gradient, so it is unlikely they would be affected by any leachable contaminants.
Buildings and infrastructure			
Made Ground **Existing A12 Road Construction (S5d)** Exceedances of Benzo(b)fluoranthene, Benzo(a)pyrene, and Dibenz(a,h)anthracene in two soil and tarmac samples	Proposed scheme associated infrastructure **(R4)**	Direct Contact with aggressive ground conditions **(P10)**	Based on the limited number of exceedances of the generic screening criteria for soil it is considered that the probability of the pollution linkage to property from these contaminants is low.
		Hazardous ground gases in confined spaces (formed as part of the proposed scheme) leading to explosion **(P11)**	The gas risk assessment undertaken shows that most of the proposed scheme has low gas generating potential.
Contaminants in the Groundwater Widespread exceedances of general inorganic analytes and metals / semi-metals in the secondary aquifers underlying the proposed scheme.	Proposed scheme associated infrastructure **(R4)**	Direct Contact with aggressive ground conditions **(P10)**	The groundwater has only been compared against human health and environmental guideline values, however the risk to buildings and infrastructure is considered low.

Geo-environmental recommendations

5.5.50 With the application of appropriate working practices, appropriate health and safety risk assessments, safe working methods and suitable protection measures, potential risk from soil contamination to on-site workers (construction workers and future maintenance workers), the public, and to controlled waters during construction work is considered to be generally low risk.

5.5.51 If groundwater control is required, discharge to existing surface waters must be under an Environment Agency permit or discharge consent. It is recommended that a surface water management plan is produced as part of the second iteration of the EMP.

5.5.52 All works should be undertaken using the application of appropriate working practices as outlined in CIRIA C741 'Environmental good practice on-site' (4th edition) to prevent risk to human health and controlled waters, that could involve further sampling and material segregation following the appropriate guidance.

5.5.53 Any materials to be used on the proposed scheme (including site-won materials) should be determined suitable for re-use by the adoption of suitable acceptability criteria.

5.5.54 All imported fill should be determined suitable at source prior to import as per guidance set out in the Definition of Waste: Development Industry Code of Practice (DoWCoP) – Contaminated Land: Applications in Real Environments (CL:AIRE, 2011) through acceptance of quality control certificates, or direct testing.

5.5.55 As indicated by the asphalt waste assessment, some existing asphalt horizons have been found to contain coal tars and which would be hazardous waste for disposal. These materials are likely to remain in-situ. However, the Environment Agency has released Regulatory Position Statement (RPS) 075, which allows the re use of treated asphalt waste containing coal tar on construction projects. Such materials could therefore potentially be reused as part of the proposed scheme if required.

5.6 Risk register

5.6.1 The scoring system used in the geotechnical and geo-environmental risk register is shown in Tables 5.21, 5.22, 5.23, 5.24. The geo-environmental risk register is shown in Table 5.25.

Table 5.21 Probability of occurrence

Probability (P)	
Very High / >70% chance	5
High / 50% to 70% chance	4
Medium / 30% to 50% chance	3
Low / 10% to 30% chance	2
Very Low / <10% chance	1

Table 5.22 Impact of occurrence

Impact (I)		Time	Health and safety	Environment
Very High	5	>10 weeks impact on completion date	**Safety:** Multiple fatalities **Health:** Significant possibility of significant harm. Category 1 (Part IIA site). Contamination heavily restricts proposed use of land without remediation	**Controlled Waters:** Loss of, or extensive change to an aquifer or river. Loss of regionally important water supply. **Habitat:** Significant damage to a designated site (i.e. SSSI), significant loss of biodiversity. **Soils:** Physical removal or permanent sealing of soil
High	4	> 1 week impact on completion date	**Safety:** One fatality. **Health:** Significant possibility of significant harm. Category 2 (Part IIA site). Contamination restricts proposed use of land without remediation.	**Controlled Waters:** Partial loss or change to an aquifer. Degradation of regionally important public water supply or loss of significant commercial/ industrial/ agricultural supplies. **Habitat:** Moderate damage to a designated site (i.e. SSSI), moderate loss of biodiversity **Soils:** Permanent loss of soil function through; degradation, compaction, erosion of soil resource.
Medium	3	> 4 weeks on activity: < 1 week on completion date	**Safety:** Major injury. **Health:** Category 3 (suitable for use). Good practice measures to minimise harm to human health.	**Controlled Waters:** Potential low risk of pollution to groundwater. **Habitat:** Minor damage to a designated site (i.e. SSSI), minor loss of biodiversity. **Soils:** Temporary loss / reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource).
Low	2	1 to 4 weeks on activity: none on completion date	**Safety:** Minor injury. **Health:** Category 4 (suitable for use). Good practice measures to minimise harm to human health.	**Controlled Waters:** Potential but negligible risk of pollution to groundwater. **Habitat:** Negligible damage to a designated site (i.e. SSSI), negligible loss of biodiversity. **Soils:** Temporary negligible loss / reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through negligible degradation, compaction, erosion of soil resource).

Impact (I)		Time	Health and safety	Environment
Very Low	1	1 week to activity: none on completion date	**Safety:** Negligible. **Health:** Negligible harm. Contaminant concentrations substantially below category 4.	**Controlled Waters:** No measurable impact upon an aquifer and/or groundwater receptors, and no risk of pollution from spillage. **Habitat:** No damage to a designated site (i.e. SSSI), no loss of biodiversity. **Soils:** No discernible loss / reduction of soil function(s) that would restrict current or approved future use.

Table 5.23 Overall risk rating

Risk rating (R)	Classification
13 to 25	**Extreme Risk** - Unacceptable except in extraordinary circumstances; all control measures must be taken regardless of cost.
9 to 12	**Substantial Risk/Early Attention** - All practicable measures must be taken to reduce the level of risk; Tolerable only where further risk reduction is impracticable or disproportionate to the risk involved.
5 to 8	**Moderate Risk/Regular Attention** - Tolerable, but efforts should be made to reduce the risk where cost effective and reasonably practicable.
1 to 4	**Low Risk/Monitor** - Ensure controls are adhered to and activity need not alter.

Table 5.24 Risk rating matrix

Likelihood of occurrence (probability)	Impact				
	5. Very high	4. High	3. Medium	2. Low	1. Very low
5. Very Likely	25	20	15	10	5
4. Likely	20	16	12	8	4
3. Probable	15	12	9	6	3
2. Unlikely	10	8	6	4	2
1. Negligible	5	4	3	2	1

Table 5.25 Geo-environmental risk register

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
GEO-ENVIRONMENTAL											
1	Exposure of construction workers and nearby site users to potentially contaminated materials and soils associated with on-site land uses and proximal off-site historical land uses.	Excavation works are likely to expose any contamination within the soil to the surface.	3	3	9	Health impact to construction workers. Restriction on reuse of soils excavated. Possible waste disposal costs and re-sourcing of alternative materials. Delays to program	Intrusive ground investigation has been undertaken to investigate and characterise soils. Analysis of a number of samples of Made Ground and natural deposits are generally below the generic screening criteria for soils. There is potential to uncover potentially contaminated materials not identified during the GI. Watching brief method of working is required during excavation works.	1	3	3	Good working practices appropriate should be implemented during works including the use of Personal Protective Equipment (PPE) to reduce worker's exposure to soils and the use of dust suppression measures to prevent exposure of offsite users to windblown contaminated dust during works. Contractor to produce a contamination response protocol should potentially contaminated materials be encountered during works. Contractor to implement watching brief during excavation work so suspected contaminated materials are properly identified and segregated to avoid cross contamination. Sampling and laboratory analysis should be undertaken to determine suitability for reuse or disposal option. Also, assessment of risks to workers from exposure to the materials should be undertaken.
		Soil identified containing asbestos containing materials	4	3	12		Minimise excavation of contaminated soils where possible, especially in the area of where asbestos containing materials have been identified and areas where hazardous concentrations of hydrocarbons were detected. Compile a Materials Management Plan for the proposed development. Undertake further testing as necessary during excavation to inform material re-use/disposal options.	1	3	3	
		Excavation works are likely to expose any historical pavements possibly containing coal tars to facilitate the widening of existing embankments.	4	3	12		Analysis of historical pavement and subsoils indicated analytes above the generic screening criteria for soils appropriate for assessment of risk to human health from soil contamination. There is potential to uncover historical pavements containing coal tar that were not identified during the GI. Watching brief method of working is required during excavation works. The Regulatory Position Statement (RPS) 075, allows the re use of treated asphalt waste containing coal tar on construction projects. The construction should follow the guidance in RPS 075 so that such materials could potentially be reused as part of the proposed scheme if required.	1	3	3	

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
2	Contamination of groundwater	Offsite sources - Potential for contaminants associated with offsite sources of land contamination leaching into the underlying groundwater.	4	3	12	Contamination of groundwater including sensitive aquifers within shallow superficial deposits. Potential clean-up costs and project delays if impacted	Three monthly post GI groundwater monitoring has been undertaken as part of the GI programme to obtain baseline groundwater conditions across the proposed scheme. Review of available chemical data indicate that groundwater underlying the proposed scheme have generally poor chemical quality as a number of potential contaminants were recorded above the relevant screening criteria for controlled waters. Groundwater is unlikely to be encountered in substantial quantities during construction of design sections 1 and 2 which would require dewatering and thus the risk is unlikely. For design section 3 (junction 23 to 25) some excavations may require dewatering. There is potential for further contamination of groundwater through contaminants that may be drawn from offsite sources requiring adequate control measures (as recommended in C648) should be put in place prior to the proposed works. Groundwater monitoring should be undertaken during and post excavation works to access impact on baseline conditions.	2	3	6	Groundwater management plan to be produced in the second iteration of the EMP to prevent pollution of the secondary aquifer underlying the scheme. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted during excavation.
		Onsite sources - Fill materials containing leachable contaminants in sensitive locations on the A12 scheme	3	3	9	Leaching of contaminants from soil placed on the A12 scheme into groundwater. Potential contamination of sensitive aquifers and source protection zones. Potential clean-up costs and project delays if impacted.	Soil leachability analysis and assessment of laboratory data have been undertaken as part of the A12 GI programme. Leachable contaminants were recorded above the relevant screening criteria for controlled waters. Any fill materials to be used on the proposed scheme should be determined suitable for reuse by the adoption of an appropriate acceptability criteria derived from a DQRA.	1	3	3	Groundwater management plan to be produced and implemented as part of CEMP to prevent pollution of the secondary aquifers underlying the scheme and source protection zones. Designer recommended mitigation measures should be adopted during works.
3	Pollution / contamination of surface water – Dewatering excavations	Uncontrolled discharge of water pumped out from excavations during dewatering – groundwater underlying the proposed scheme shows poor chemical quality.	3	3	9	Pollution of surface water. Potential clean-up costs and project delays if impacted. Potential fines and prosecution. Possible high costs for pumped water desilting and treatment prior to discharge.	The uncontrolled discharge of groundwater associated with dewatering / ground water lowering associated with construction may contaminate surrounding surface waters and must be avoided. Further DQRA is required for the management of any dewatering and to support a permit for discharge. Monitoring of all the surface watercourses on or close the proposed scheme to be undertaken to establish baseline conditions prior to works. Additional monitoring to be undertaken during and post excavation works to assess impact of works on baseline conditions.	2	3	6	It is recommended that a surface water management plan is produced and implemented as part of the CEMP. Discharge to existing surface waters surrounding the proposed scheme must be under the EA permit or discharge consent. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted during construction

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
4	Pollution / contamination of surface water – Direct run-off from stockpiles	Direct run-off of contaminants and silt from stockpiled soils to surface watercourses located adjacent to proposed scheme. Migration of leached contaminants in groundwater to surface water (groundwater underlying the A12 is likely to provide base flow to surrounding rivers and other surface waters)	3	3	9	Pollution of surface water Potential clean-up costs and project delays if impacted. Potential fines and prosecution Possible high costs for providing containment for pumped water on site and associated laboratory analysis costs for contamination testing to determine appropriate disposal route. Possible costs for offsite disposal if laboratory test confirms presence of gross contamination.	Three – monthly post GI groundwater monitoring has been undertaken as part of the A12 GI programme. Results of analysis confirmed that groundwater underlying the proposed scheme have generally poor chemical quality with potential contaminants recorded above the relevant screening criteria for controlled waters. Runoffs from excavated stockpiled materials could potentially pollute and silt up surface waters. Excavated materials should be stored appropriately away from watercourses. Monitoring of all the surface watercourses on or close to the proposed scheme would be undertaken to establish baseline conditions prior to works. Additional monitoring would also be undertaken during and post excavation works to assess impact of works on baseline conditions.	2	3	6	It is recommended that a surface water management plan be produced and implemented as part of the CEMP. Adequate containment should be provided where shallow groundwater was encountered during monitoring. Chemical testing of water is required to determine contamination status and disposal options. Discharge to existing surface waters surrounding the proposed scheme should be under the EA permit or discharge consent. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted during construction
5	Pollution / contamination of surface water – Placement of fill / existing fill	Direct run-off of contaminants and silt from fill materials containing leachable contaminants on sensitive locations on the A12 scheme. Migration of leached contaminants in groundwater to surface water (groundwater underlying the A12 is likely to provide base flow to surrounding rivers and other surface waters)	3	3	9	Pollution of surface water located close to the A12 where fill materials would be placed. Potential clean-up costs and project delays if impacted. Potential fines and prosecution.	Soil leachability analysis and assessment of laboratory data have been undertaken as part of the A12 programme. Leachable contaminants were recorded above the relevant screening criteria for controlled waters. Any fill materials to be used on the A12 scheme should be determined suitable for reuse by the adoption of an appropriate acceptability criteria derived from a DQRA. Monitoring of all the surface waters located close to the locations where fill materials would be placed should be undertaken to establish baseline conditions prior to the A12 construction works. Additional monitoring should be undertaken during and post construction of the A12 assess the impact of construction works on baseline conditions.	2	3	6	It is recommended that a surface water management plan be produced with and implemented as part of the CEMP. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted during construction.

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
6	Hazardous ground gases associated with offsite historical landfill located within 250m.	Potential migration of ground gases from offsite landfills through permeable strata.	3	3	9	Exposure of construction workers to ground gases during excavation works. Inhalation of ground gases could lead to asphyxiation Health impact issues.	Ground gas monitoring has been undertaken as part of the A12 GI programme. Post field work six - weekly ground gas monitoring was completed. Available monitoring data indicate low levels of toxic or potentially explosive gases in all locations. Proposed works would involve shallow open excavation - confined spaces are not likely to be created. Based on the monitoring results low levels of ground gases would likely vent into the atmosphere during works.	1	3	3	Method statements and risk assessment for gas monitoring in excavations should be done in accordance with HSE (2013) RR973 - Review of alarm setting for toxic gas and oxygen detectors.

6 Borrow pits

6.1 Description of the design elements

6.1.1 To accommodate the development of the proposed scheme, remodelling of the existing site terrain is required. In order to complete this remodelling, fill material is required locally to raise ground levels to the required levels. It is proposed to source construction materials in part, from local borrow pits located across the site area. A number of the potential borrow pits have been identified primarily due to their strategic location in relation to the proposed scheme and areas requiring the majority of fill.

6.1.2 Only the four potential borrow pits (BPE, BPF, BPI and BPJ) selected following the ground investigation have been included in this assessment.

6.1.3 Table 6.1 provides a summary of the proposed borrow pits. The locations of the borrow pits are shown on Plates 2.1, 2.2 and 2.3, in Section 2.2 of this report.

Table 6.1 Summary of proposed borrow pits

Borrow pit ref.	Location	Proposed maximum excavation depth (mbgl)	Restoration proposals	Comments
BP-E	Northeast of Hatfield Peverel	4.5*	TBC	Preferred Borrow Pit
BP-F	South of Witham	4	TBC	Preferred Borrow Pit
BP-I	East of Rivenhall End	17	TBC	Preferred Borrow Pit
BP-J	South East of Kelvedon	7	TBC	Preferred Borrow Pit
* The Borrow Pit Report [TR010060/APP/7.8] specifies anticipated excavation depths and maximum excavation depths to provide flexibility in case archaeological remains are present. The excavation depths in this table represent the maximum depths.				

6.2 Site history

6.2.1 Based on the review of historical mapping and aerial photographs obtained with the Landmark Envirocheck data purchased for the scheme, all the borrow pit sites are shown on the earliest map (1881) as predominantly agricultural land with no significant changes over time. On present day maps, all the borrow pit sites are still shown as undeveloped.

6.2.2 Key geo-environmental features identified on the historical maps (on and within 250m of the sites) which are considered as potential sources of land contamination are summarised in Table 6.2 and 6.4. Details of historical land use changes over time are presented in the borrow pits PSSR.

6.3 Geology

6.3.1 The superficial deposits and bedrock underlying each of the borrow pits are summarised in Table 6.2. The ground conditions encountered during the GI are summarised in Section 6.8 of this report. Data on mapped geology was obtained from the BGS GeoIndex website.

6.4 Hydrogeology

6.4.1 The aquifer underlying each of the borrow pits are summarised in Table 6.2. The Environment Agency Aquifer Definitions are as follows:

6.4.2 Principal Aquifers - These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.

6.4.3 Secondary Aquifers - These include a wide range of rock layers or drift deposits with an equally wide range of water permeability and storage. Secondary aquifers are subdivided into two types:

- Secondary A - Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.
- Secondary B - Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.

6.4.4 Secondary Undifferentiated - Has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

6.4.5 Unproductive Strata - These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

6.4.6 Hydrogeological data in the form of; strike and rise to groundwater levels recorded whilst drilling, falling and rising head tests and ground water monitoring have been provided as part of the GIs.

6.4.7 Data on groundwater abstractions was obtained from local authorities and the Environment Agency. Data on mapped geology was obtained from the BGS GeoIndex website and data on aquifer designations from DEFRA's MAGIC website.

6.4.8 The following limitations apply to the data sources:

6.4.9 Information contained within draft borrow pit factual reports received in November 2020 have been used in the assessment.

6.4.10 It is assumed that the dip data are presented as metres below ground level (m bgl) with conversion of data to meters Above Ordnance Datum (mAOD) based on the ground levels shown in the AGS data set as of 26 November 2020., The levels are given to one decimal place, so the accuracy of the data is uncertain.

6.4.11 For private water supplies (PWS) the data from Colchester City Council is still to be mapped. This only affects borrow pit J.

6.4.12 The groundwater dependency of LNRs and LWSs is an initial desk-based assessment, based largely on mapped water features and brief citations of the sites.

6.4.13 For groundwater receptors (abstractions and Groundwater Dependent Terrestrial Ecosystems - GWDTEs) a search radius of 1km from the borrow pit boundaries has been considered.

6.5 Hydrology

6.5.1 Based on available maps and a review of the site specific Envirocheck digital data, some of the borrow pit locations are situated near to or have a major/secondary water course crossing them. Surface water features within the vicinity of the borrow pits are shown on Plates 6.1, 6.2, and 6.3 below.

6.5.2 The hydrological features identified on each of the borrow pits are summarised in Table 6.2.

Plate 6.1 Surface water features within the vicinity of borrow pit E and F

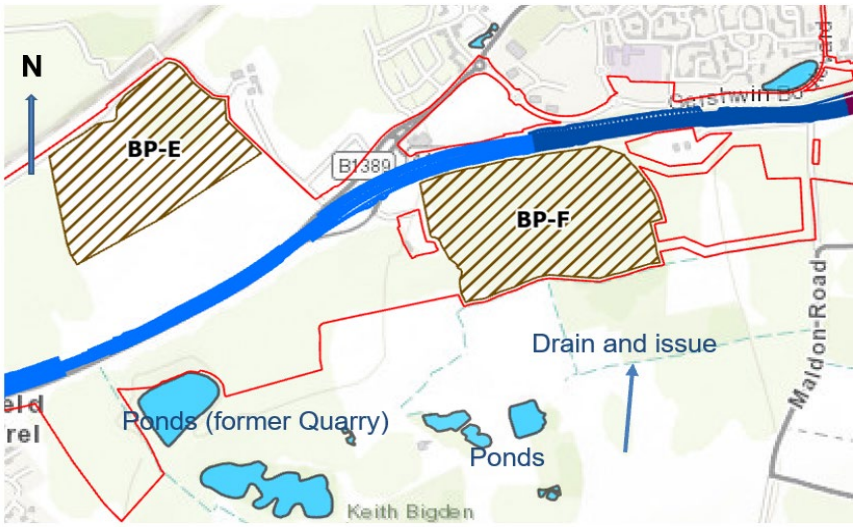


Plate 6.2 Surface water features within the vicinity of borrow pit I

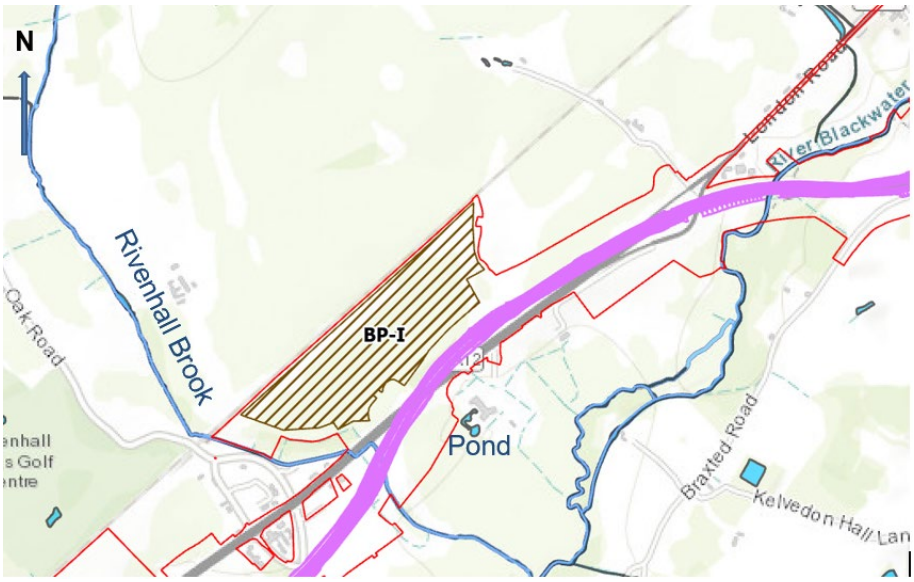
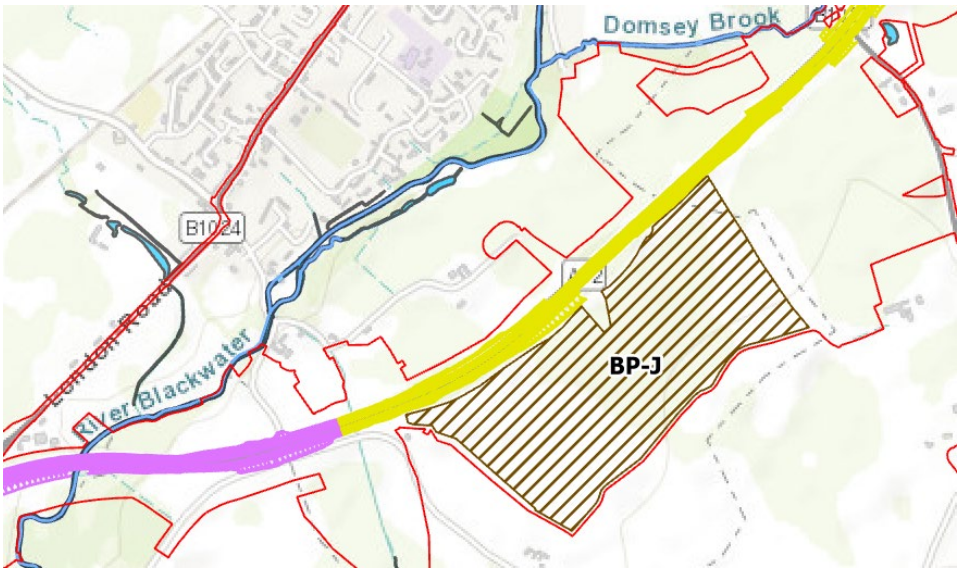


Plate 6.3 Surface water features within the vicinity of borrow pit J



6.6 Potential land contamination constraints

6.6.1 As part of the initial desk study assessment of the borrow pits potential sources of land contamination identified from current and historical land uses on and within 250m of the borrow pits which could potentially impact the borrow pit sites were identified.

6.6.2 A preliminary CSM was developed which supports the identification and assessment of pollutant linkages using the source-pathway-receptor model. The model allows for the CSM to be refined as more studies are taken and information are obtained. The refined CSM updated based on the borrow pit GI information is presented in Table 6.4.

6.7 Field studies and laboratory analysis

6.7.1 The ground investigation of all the borrow pits (including the descoped ones) comprised of:

- A total of 90 Cable Percussive Boreholes to a maximum depth of 20.5m below existing ground level (begl), and an average depth of 11.5m begl.
- A total of 175 Machine Excavated Trial Pits to a maximum depth of 4.5m begl, and an average depth of 3.8m begl.

6.7.2 The borrow pit GI exploratory hole locations are shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].

Laboratory analysis

6.7.3 The geo-environmental laboratory analysis undertaken as part of the borrow pits GI including the descoped borrow pts comprised:

- 199 soil chemical analysis.
- 35 soil leachability tests.
- 48 Waste Acceptance Criteria (WAC) tests.
- 60 groundwater chemical analysis. Three-monthly groundwater sampling visits were undertaken in 20 locations across all the borrow pits.

6.8 Borrow pits ground summary

6.8.1 The following section describes the ground conditions encountered during the borrow pits ground investigation as presented in the GIR.

Made ground

6.8.2 Made Ground not consisting of reworked natural material or embankment fill is typically described as soft to stiff, sandy, gravelly, silty clay and commonly contains fragments of chalk, flint, brick and organic material

Reworked natural ground deposits

6.8.3 Topsoil has not been differentiated on the logs. All material likely to be Topsoil where there is no anthropogenic material present, has been assigned by the GI contractor as Reworked Natural Deposits. This material is typically described soft to stiff, sandy, gravelly, silty clay and contains fragments of chalk, flint and organic material.

Alluvium

6.8.4 The BGS Lexicon of Named Rock Units typically describes Alluvium as normally soft to firm, consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present. The BGS Memoir describes Alluvium as soft, pale brown silty clay with traces of organic matter. Material interpreted as Alluvium has been encountered in the exploratory holes and is highly variable but typically described as: very

soft to stiff, brown / orangish brown, organic, slightly sandy, slightly gravelly, silty clay with occasional peat. The material appears to have generally been removed from beneath the existing alignment earthworks.

River terrace deposits

6.8.5 The BGS Lexicon of Named Rock Units typically describes River Terrace Deposits as sand and gravel, locally with lenses of silt, clay or peat.

6.8.6 Material interpreted as River Terrace Deposits has been encountered in the exploratory holes and is typically described as brown or orangish brown, silty sand and gravel with occasional flint cobbles, or slightly gravelly fine to coarse sand. The gravel is commonly described as fine to course, rounded to sub-rounded, of flint and quartzite.

6.8.7 Cohesive examples of this material have also been identified as 0.1 to 1.0m thick lenses within the granular deposits and are commonly described as laminated clayey fine sandy silt and can contain small amounts of organic material.

Head deposits

6.8.8 The BGS Lexicon of Named Rock Units typically describes Head as a polymict deposit (sourced from different materials) comprising gravel, sand and clay depending on upslope source and distance from source. Head often consist of poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hillwash and soil creep. Generally, the Head deposits comprise sand and gravel, locally with lenses of silt, clay or peat and organic material. The BGS Memoir describes Head as being derived from different parent materials and is therefore comprised of silty sands, silty clays and chalk free orange-brown stony clay.

6.8.9 Material interpreted as Head Deposits has been encountered in the exploratory holes. It is highly variable but typically described as soft to stiff orangish brown or brown, sandy, silty clay or clayey silt with occasional fine to medium gravel, or slightly clayey sand gravel. The generally lower strength, position of the deposits, i.e., on side slopes, and absence or reduced amount of larger chalk fragments has been used to differentiate the material from the Lowestoft Formation and other superficial deposits where possible.

Brickearth

6.8.10 The BGS Lexicon of Named Rock Units states that, Brickearth typically varies from silt to clay, usually yellow-brown and massive. The BGS Memoir describes Brickearth as light sandy loam.

6.8.11 Material interpreted as Brickearth has been encountered in the exploratory holes. It is typically described as soft to firm, brown, sandy silt or clayey sandy silt.

Glaciolacustrine deposits (formerly known as lake deposits)

6.8.12 The BGS Lexicon of Named Rock Units typically describes Glaciolacustrine Deposits as being laid down in glacial lakes and comprising silt and clay,

laminated / varved, commonly rich in organic matter, locally with interbedded peat.

6.8.13 Glaciolacustrine deposits have been differentiated from Interglacial Silt and Clay deposits by their presence within or on the Lowestoft formation.

6.8.14 Material interpreted as Glaciolacustrine Deposits has been encountered in the exploratory holes and is typically described as firm, brown, laminated clayey silt, and silty clay. The material appears to have generally been removed from beneath the existing alignment earthworks.

Interglacial silt and clay

6.8.15 The BGS Lexicon of Named Rock Units typically describes Interglacial Silt and Clay as interbedded or chaotic silt and clay deposits.

6.8.16 Interglacial Silt and Clay deposits have been differentiated from Glaciolacustrine Deposits by the absence of Lowestoft Formation at the deposits upper or lower boundary, i.e., low energy deposits downstream of the glaciers.

6.8.17 Material interpreted as Interglacial Silt and Clay has been encountered in exploratory holes and is typically described as laminated firm to stiff clayey silt and laminated firm to stiff, fine sandy clayey silt. This material is often found as 5m+ thick homogenous deposits with little variation in grain size. The material appears to have generally been removed from beneath the existing alignment earthworks.

Lowestoft Formation (formerly known as boulder clay)

6.8.18 The BGS Lexicon of Named Rock Units states that, the Lowestoft Formation forms an extensive sheet of chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content and its thickness is extremely variable. The BGS Memoir describes the local Boulder Clay, now known as the Lowestoft Formation, as grey clay with chalk inclusions.

6.8.19 Material interpreted as Lowestoft Formation has been encountered in the exploratory holes. It is typically described as firm to stiff, mottled pale orange to brown, slightly sandy, gravelly, silty clay. The gravel commonly consists of chalk, flint, sandstone, quartzite and occasionally mudstone.

Glaciofluvial deposits (formerly known as glacial sand and gravel)

6.8.20 The BGS Lexicon of Named Rock Units typically describes the Glaciofluvial Deposits as, sand and gravel, locally with lenses of silt, clay or organic material. The Glaciofluvial deposits are typically encountered beneath the Lowestoft Formation, but also outcropping above, from beneath or within the Lowestoft Formation as discrete and often discontinuous beds.

6.8.21 Material interpreted as Glaciofluvial Deposits has been encountered in the exploratory holes. It is typically described as; loose to very dense, brown, orangish brown or yellowish-brown, sandy gravel with occasional cobbles, or slightly gravelly sand. The gravel commonly consists of predominately flint gravel with occasional chalk and quartzite gravel.

Kesgrave Catchment Subgroup

6.8.22 The BGS Lexicon of Named Rock Units states that, the Kesgrave Catchment Subgroup encompasses fluvial, lacustrine and organic deposits of the pre-diversionary River Thames, and the pre-glacial soils developed on such deposits. Most of the surviving deposits are fluvial gravels, with sedimentary structures indicating deposition by a braided river. Lacustrine silts and clays and organic peats are uncommon. The BGS Memoir describes the Kesgrave sands and gravels, now known as the Kesgrave Catchment Subgroup, as containing a high proportion of rounded flint, quartz and quartzite pebbles. Secondary calcareous concretions which envelop flints are developed in the upper part of the gravels.

6.8.23 It should be noted that the current BGS GeoIndex Onshore maps indicate both the Kesgrave Catchment Group and the younger Glaciofluvial deposits to be present beneath the Lowestoft Formation around Kelvedon, with the Kesgrave being generally present to the north beneath the proposed scheme. Materials of the Kesgrave Catchment Group were not encountered in the borrow pit GI (Phase 1 GI). However, in order to differentiate these materials for the wider scheme, the following criteria has been applied:

- Glaciofluvial deposits - more angular clasts, occasional chalk, and poorer sorting.
- Kesgrave Catchment Group - well rounded, no chalk. Gravel mostly flint, commonly quartz and quartzite. Upper surface can be affected by ancient soil formation giving a reddish colouration

London Clay Formation

6.8.24 The BGS Lexicon of Named Rock Units states that, the London Clay Formation mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.

6.8.25 It commonly contains thin courses of carbonate concretions (‘cementstone nodules’) and disseminated pyrite. It also includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation. At the base, and at some other levels, thin beds of black rounded flint gravel occur in places. Glauconite is present in some of the sands and in some clay beds, and white mica occurs at some levels.

6.8.26 The London Clay Formation has been encountered in the exploratory holes. Weathered London Clay is typically described as firm to stiff orange, brown with some grey mottling silty clay. Unweathered London Clay Formation is typically described as stiff grey silty clay.

6.9 Land contamination assessment

6.9.1 Similar to the proposed scheme, a land contamination assessment was undertaken for all the borrow pits to assess potential risks to human health and controlled waters from the proposed borrow pits based on the guidance detailed in Section 5.5 of this report.

6.9.2 The ground investigation findings and the laboratory analysis results for soils, soil leachate and groundwater analysis undertaken for the proposed four borrow pits are summarised in Table 6.2 below.

Table 6.2 Borrow pits GI findings summary table

	BP-E	BP-F	BP-I	BP-J
Location	East of Hatfield Peverel	South West of Witham	East of Rivenhall End	South of Kelvedon
Topography	The north west of the borrow pit forms a local high at approximately 51m AOD, with levels falling generally to the east and south to approximately 45m AOD.	Ground levels local to the borrow pit generally fall from west to east, and within the borrow pit Order Limits vary from approximately 40m AOD in the west, to 22m AOD in the east.	Ground levels local to the borrow pit generally fall from north west to south east, and within the borrow pit Order Limits vary from approximately 30m AOD in the north west, to 21m AOD in the south east.	Ground levels local to the borrow pit generally fall from south east to north west, and within the borrow pit Order Limits vary from approximately 44m AOD in the south east, to 26m AOD in the north west. A series of shallow valley and ridge features are present to the south east of the borrow pit and extend in a generally north westerly direction across the borrow pit, with one valley located along the south westerly boundary.
BGS Geology	**Superficial:** Head Deposits, Lowestoft Formation over Glaciofluvial Deposits **Solid:** London Clay Formation	**Superficial:** Head Deposits, Brickearth, Lowestoft Formation, Glaciofluvial Deposits **Solid:** London Clay Formation	**Superficial:** Head Deposits, Lowestoft Formation and relatively small area of River Terrace Deposits at the eastern corner. **Solid:** London Clay Formation	**Superficial:** River Terrace Deposits, Lowestoft Formation, Glaciofluvial Deposits **Solid:** London Clay Formation
STATS	**On / Crossing Site** None indicated **Adjacent to Site** MPG	**On / Crossing Site** Foul Water Drain High Pressure Gas Main **Adjacent to Site** EX11KV	**On / Crossing Site** OE11KV **Adjacent to Site** OE11KV Wastewater	**On / Crossing Site** Wastewater **Adjacent to Site** OE11KV
Hydrology	**Surface Water Features:** Ground levels fall gently to the southeast. Pond - On-Site: north-western quadrant Reservoir - 180 m south Tertiary Watercourse -120 m south **River Quality:** No data available **Flood Risk:** Environment Agency river and sea flood maps indicate the area is not liable to flooding from rivers. **Surface Water Runoff:** Surface water run-off towards the borrow pit is unlikely. Surface water run-off from the borrow pit is likely to be to the east and south.	**Surface Water Features:** Ground levels fall to the east towards the River Blackwater which is situated approximately 1.1km from the site. A small watercourse (drain) present on the site's southern boundary. **River Quality:** No data available **Flood Risk:** Environment Agency river and sea flood maps indicate the area is not liable to flooding from rivers. **Surface Water Runoff:** Surface water run-off towards the borrow pit is likely to be from the west. Run-off from the borrow pit is likely to be in an easterly direction towards The River Blackwater.	**Surface Water Features:** Ground levels fall gently to the south and southeast towards the Rivenhall Brook and River Blackwater. The Rivenhall Brook is approximately 100m to the west of the site and the River Blackwater 600m to the southeast. **River Quality:** No data available **Flood Risk:** Environment Agency river and sea flood maps indicate the area is not liable to flooding from rivers. **Surface Water Runoff:** Surface water run-off towards the borrow pit is likely to be from the north west. Run-off from the borrow pit is likely to be in a south and south easterly direction towards the Rivenhall Brook.	**Surface Water Features:** Ground levels fall to the northwest towards the Domsey Brook and River Blackwater. The Domsey Brook is approximately 150m to the north of the site and the River Blackwater 400m to the northwest. A spring is mapped approximately 350m to the northwest. **River Quality:** No data available **Flood Risk:** Environment Agency river and sea flood maps indicate the area is not liable to flooding from rivers. **Surface Water Runoff:** Surface water run-off towards the borrow pit is likely to be from the south east and is likely to be most concentrated in the shallow valley features. Run-off from the borrow pit is likely to be in a north westerly direction towards The River Blackwater.

	BP-E	BP-F	BP-I	BP-J
Hydrogeology	**Superficial:** Head Deposits - Unproductive Lowestoft Formation - Secondary Undifferentiated aquifer **Solid:** London Clay Formation – Unproductive aquifer **LWSs / LNRs - potential for GWDTEs:** No LWSs or LNRs within 1km of the site. **Potential GWDTEs identified in phase 1 habitat survey:** Nearest site (wet woodland) is approximately 800m from the proposed borrow pit. **Encountered Groundwater Conditions:** Groundwater generally not encountered during borehole drilling with the shallowest water strike being at 4.1mbgl, with the water level rising to 3.2 m begl in 20 minutes (BH2031). No trial pits encountered groundwater. Rest water levels are typically shown as being 10mbgl to 15m begl. Only in the southwest of the site is shallower groundwater encountered, with a rest water level of approximately 4m begl recorded in BH2031 where the London Clay was found to be shallower. Based on the limited groundwater level data and topography, groundwater flow direction is likely to be in a broadly south-easterly direction. **Permeability:** Permeability variable head tests were undertaken in 4 No. boreholes completed in the sands and gravels. Permeability in 2 No. of the boreholes was too high to measure with the method used. The third test showed a permeability of 2.81E-06m/s (0.24m/day). The 4th test involved adding water to a dry borehole and showed water soaked away in 2.5 minutes.	**Superficial:** Brickearth - Secondary B aquifer. Lowestoft Formation - Secondary Undifferentiated aquifer **Solid:** London Clay Formation – Unproductive aquifer **LWSs / LNRs - GWDTEs:** No LWS or LNRs within 1km of the site. **Potential GWDTEs identified in phase 1 habitat survey:** Nearest site (wet woodland) is approximately 350m to the south of the proposed borrow pit. **Encountered Groundwater Conditions:** Groundwater is expected to be relatively shallow over most of the site (all but one of the boreholes recorded groundwater levels within 2m of the ground surface). However, groundwater was generally not encountered during borehole drilling with only one borehole recording a water strike, and this being at 7.4mbegl, with the water level rising to 7.2m begl in 20 minutes (BH2038). It was this borehole which had the deepest groundwater level measured in the completed boreholes with the groundwater level being deeper than 5m. four of the 12 No. trial pits encountered groundwater. Based on the limited groundwater level data and topography, groundwater flow direction is likely to be in a broadly easterly to south-east direction towards the River Blackwater. **Permeability:** Permeability variable head tests were undertaken in four boreholes which were largely completed in the near-surface clay deposits. Permeability in three of the boreholes was too low to measure with the method used. The fourth test showed a permeability of 5.80E-07m/s (0.05m/day). As the geology would	**Superficial:** Head Deposits - Unproductive Lowestoft Formation - Secondary Undifferentiated aquifer **Solid:** London Clay Formation – Unproductive **LWSs / LNRs - potential for GWDTEs:** 550m from Hoo Hall Meadow - assessed as having moderate groundwater dependency and 950m from Braxted Park - assessed as having high groundwater dependency. **Potential GWDTEs identified in phase 1 habitat survey:** Nearest site (wet woodland) is approximately 20m to the west of the proposed borrow pit with further sites (wet woodland) approximately 150m further west. **Encountered Groundwater Conditions:** The groundwater level is expected to generally be at around 3 to 5m begl. Groundwater was recorded during borehole drilling in five of the eight boreholes with the water strikes being recorded at between 3.2 and 10.0m begl. The water levels rose by 2 to 3m in most of the boreholes following the strike, indicating a degree of groundwater confinement. Five of the 11 trial pits encountered groundwater seepages. In the monitoring boreholes, the shallowest rest water levels in five boreholes are shown as typically being 3 to 4m begl, and in the remaining three the rest water level is shown as being within 1m of the ground surface. Based on the limited groundwater level data and topography, groundwater flow direction is likely to be in a broadly southerly direction towards the Rivenhall Brook. **Permeability:** Permeability variable head tests were undertaken in four boreholes. Where completion was in the sand and gravel deposits one of the two tested boreholes	**Superficial:** River Terrace Deposits - Secondary A aquifer. Lowestoft Formation - Secondary Undifferentiated aquifer Glaciofluvial Deposits - Secondary A aquifer. **Solid:** London Clay Formation – Unproductive **LWSs / LNRs - potential for GWDTEs:** 400m from Brockwell Meadows - assessed as having moderate groundwater dependency; 500m from Inworth Wood - assessed as having low groundwater dependency. **Potential GWDTEs identified in phase 1 habitat survey:** Nearest site (wet woodland) is approximately 150m to the north of the proposed borrow pit. **Encountered Groundwater Conditions:** Groundwater levels are variable across the site. Groundwater was recorded during borehole drilling in three of the 14 boreholes with the water strikes being recorded at 0.4, 2.2 and 5.2m begl. The water levels showed small rises following the strike. Only three of the 42 trial pits encountered groundwater seepages. In the 14 monitoring boreholes, three have been recorded as being dry and a fourth recorded a groundwater level of approximately 9 to 10mbgl. In the other boreholes, shallower groundwater levels were recorded ranging from approximately 0.6 to 4.0m begl. Based on the limited groundwater level data and topography, groundwater flow direction is likely to be in a broadly north-west direction towards the Domsey Brook and River Blackwater. **Permeability:** Permeability variable head tests were undertaken in nine boreholes. Permeability varies across the site although only one permeability test was analysed as either; the water level didn't change during the test (in give boreholes which shows low permeability) or the test was over too quick (in three boreholes, showing high permeability). In the one borehole where a result was calculated (BH2071 which monitors a dominantly clay

	BP-E	BP-F	BP-I	BP-J
		indicate, permeability is low across most, if not all, of this borrow pit site.	showed fast groundwater inflow. For one borehole, the water inflow was too quick to allow a permeability value to be calculated and for the second, a permeability of 6.00E-05m/s (5.2m/day) was calculated. The other second tests were in boreholes completed largely in clay superficial or London Clay deposits and the permeability was too low to calculate a permeability value (no change in groundwater head in 20 minutes).	horizon) the permeability was 8.05E-07m/s (0.07m/day).
Licensed Groundwater Abstractions and PWS within 1km	**Ground Water Abstractions:** 250m from an agricultural abstraction and 700m from an agricultural abstraction. Two identified to the east of the proposed borrow pit, approximately 100m and 200m from the site's boundary.	**Ground Water Abstractions:** 300m and 650m from 2 No. agricultural abstractions One PWS is situated approximately 300m to the northeast of the proposed borrow pit.	**Ground Water Abstractions:** No licensed groundwater abstractions are identified within 1km of the borrow pit boundary. Two PWS have been identified within 1km of the site. The closest is approximately 450m to the northwest with the second one being approximately 950m to the west.	**Ground Water Abstractions:** The eastern half of the site is situated in a groundwater SPZ zone 3 (total catchment). The nearest identified PWS is approximately 1km to the west.
Confirmed Ground Model The following Ground Models have been based on the final GI factual report AGS data as of November 2021 Note the superficial deposits are often impersistent and of variable thickness. In particular, the Glaciofluvial Deposits often form interbeds within, above and or below the Lowestoft Formation. Levels and thicknesses are therefore provided for information only and should be viewed with caution and are not suitable for volumetric determinations. A summary for Glaciofluvial Deposits has only been provided where a 'significant' thickness has been recorded.	• Made Ground/Reworked Natural Deposits 0.0 to 0.6m begl (typically 0.3m begl): Soft to firm brown slightly sandy slightly gravelly silty CLAY/clayey SILT. Gravel is subangular and subrounded fine to coarse flint. With occasional to frequent rootlets. Maximum thickness was recorded in BH2027 • Made Ground 0.0 to 0.5m begl (typically 0.30m begl): Brown sandy gravelly silty CLAY/clayey SILT. Gravel is angular to subrounded fine to coarse flint. Occasional brick fragments. Maximum thickness was recorded in BH2030 and BH2031. • Head Deposits 0.3 to 2.2m begl (typical thickness 1.4m). Encountered more prominently to the east of the site. • Lowestoft Formation: 0.3 to 16.8m begl. (typical thickness 9.9m). • Glaciofluvial Deposits: 4.1 to 20.0m begl (typical thickness 6.4m). • London Clay: 8.7 to >20.5m begl (Not proven). In summary, to an anticipated borrow pit depth of 4.0m begl, available materials are indicated to consist of predominately; Lowestoft Formation with localised Head Deposits.	• Made Ground/Reworked Natural Deposits 0.0 to 1.0m begl (typically 0.3m begl): Soft brown slightly sandy slightly gravelly CLAY/clayey SILT. Gravel is subangular and subrounded fine to coarse flint, with occasional to frequent rootlets. Maximum thickness was recorded in TP1802. • Made Ground 0.0 to 1.2m begl (typically 0.4m begl): Brown sandy gravelly CLAY/SILT. Gravel is angular to subrounded fine to coarse flint. Occasional brick fragments. Maximum thickness was recorded in BH2025 and BH2026. • Head Deposits 0.4 to 1.8m begl (typical thickness 0.6m). • Brickearth: 0.3 to 2.3m begl (typical thickness 1.1m). • Lowestoft Formation: 0.3 to 7.8m begl. (typical thickness 2.2m). • Glaciofluvial Deposits: 0.7 to >4.0m begl (typical thickness where proven 2.0m). • London Clay: 0.3 to >10.0m begl (Not proven).	• Made ground/reworked Natural Deposits 0.0 to 0.7 (typically 0.3m begl): Soft dark brown slightly sandy slightly gravelly CLAY/SILT. Gravel is fine to coarse subangular and angular flint and frequent rootlets. Maximum thickness was recorded inBH2060 • Head Deposits 0.3 to 2.5m begl (typical thickness 1.7m). • River Terrace Deposits: 1.1 to 2.9m begl (thickness 1.8m) Only encountered in one exploratory hole in the southern end of the site. • Lowestoft Formation: 0.2 to 10.3m begl. (typical thickness 4.9m). • Glaciofluvial Deposits: 1.0 to >10.5m begl (typical thickness where proven 2.5m). • London Clay: 6.0 to >10.5m begl (Not proven). In summary, to an anticipated borrow pit depth of 4.0m begl, available materials are indicated to consist of predominately; Lowestoft Formation with localised Brickearth, Head Deposits and possibly localised River Terrace Deposits to the	• Made Ground/Reworked Natural Deposits 0.0 to 0.9m begl (typically 0.4m begl): Soft to firm brown slightly sandy slightly gravelly SILT. Gravel is angular, subangular and subrounded fine to coarse flint with occasional to frequent rootlets. Maximum thickness was recorded in TP1869. • Made Ground 0.0 m to 1.0 m begl (typically 0.3 m begl): Soft dark brown slightly sandy slightly gravelly CLAY. Gravel is subangular and subrounded fine to coarse sandstone, brick and flint. Maximum thickness was recorded in TP1854A, TP1854A was greyish, reddish brown slightly gravelly to fine SAND with brick, asphalt, wood, cloth, slag, clinker and suspected asbestos containing materials. • Head Deposits 0.3 to 1.6m begl (typical thickness 0.7m). • River Terrace Deposits: 0.2 to 4.9m begl (typical thickness 1.8m). • Lowestoft Formation: 0.2 to 10.1m begl. (typical thickness 4.2m). • Glaciofluvial Deposits: 1.3 to >10m begl (typical thickness 5.4m).

	BP-E	BP-F	BP-I	BP-J
		In summary, to an anticipated borrow pit depth of 4.0m begl, available materials are indicated to consist of predominately; Lowestoft Formation and London Clay. Granular layers/beds of Glaciofluvial Deposits are indicated within the Lowestoft Formation particularly in the north west. Localised Brickearth and Head Deposits at shallow depth may be encountered.	south. Interbeds of Glaciofluvial Deposits have been noted in the Lowestoft Formation	• London Clay: 1.7 to >10.5m begl (Not proven). In summary, to an anticipated borrow pit depth of 4.0m begl, available materials are indicated to consist of predominately; Lowestoft Formation with localised Head, Brickearth and River Terrace Deposits. Glaciofluvial Deposits at depth locally beneath a cover of Lowestoft Formation.
Potential Sources of Land Contamination	**On site:** • Made ground encountered on site (possibly associated with a pond and a historical small structure near the pond). • Potential agricultural use of pesticides and herbicides on site. **Off site:** • Potential groundwater contamination on site associated with the railway embankment approximately 50m north. • Potential fuel leaks / spills in groundwater deriving from the used car dealership 50m to the south-east and potential agricultural use of pesticides and herbicides associated with the historical use of the site as a nursery.	**On site:** • Made ground encountered on site (possibly associated with a historical track on site) • Potential agricultural use of pesticides and herbicides on site. **Off site:** • Potential groundwater contamination associated with the petrol filling station 100 m to the north. • Potential agricultural use of pesticides and herbicides.	**On site:** • Made Ground encountered on site. • Potential agricultural use of pesticides and herbicides on site. **Off site:** • Unknown contaminants within the made ground associated with the railway and A12 embankments. Potential groundwater contamination associated with a dealership and petrol station at 120m to the south.	**On site:** • Made Ground and suspected asbestos containing sheets encountered on site. associated with historical infilled land. • Potential agricultural use of pesticides and herbicides on site. **Off site:** • Potential groundwater contamination associated with farms yards and car parks adjacent to site. Potential groundwater contamination associated with historical infilled mineral extraction pits located to the north-east and north-west boundaries of the site.
Ground Investigation Findings relative to Land Contamination – Soils and Soil Leachate	Made Ground was encountered in BH2030, BH2031, TP1779, TP1780, TP1787 and TP1789. These positions had occasional brick fragments noted in their logs. 15 samples were tested comprising of Made Ground/Natural Reworked (three), Head Deposits (three) and Lowestoft Formation (nine). Concentrations of all determinands fell below the GAC for commercial / industrial land use (no exceedances). Asbestos was not identified in any of the 15 samples screened. Soil leachate analysis were undertaken on four samples. (BH2026 in Made Ground /Head Deposits at 0.30-0.50m begl; TP1788 in Head Deposits at 0.80-1.00m begl), (BH2031 in Lowestoft Formation at 0.60-0.70m begl; TP1777 in Lowestoft Formation at 1.40–1.50m begl). Results (obtained from eluate analysis (2:1) part of the WAC tests) recorded	Made Ground was encountered in BH2032 and BH2034 - BH2036. These positions had occasional brick fragments noted in their logs. 14 No. samples were tested as follows: comprising of Made Ground (four), Made Ground/Natural Reworked (three), Lowestoft Formation (three), Head (one), Brickearth (one) and Glaciofluvial deposits (two). Concentrations of all determinands fell below the generic screening criteria for soils (no exceedances). Asbestos was not identified in any of the 14 samples screened. Three leachate samples were analysed, total cyanide concentration exceeds the EQS of 1µg/l in TP1794.	Made Ground/Natural Reworked Ground was encountered in 20 of the positions investigated. The Made Ground primarily consisted soft dark brown slightly sandy slightly gravelly CLAY/SILT. Gravel is fine to coarse subangular and angular flint. In five of the above locations brick was encountered. 15 samples were tested comprising of Made Ground (five) and Lowestoft (10). All determinands fell below the generic screening criteria for soils (no exceedances). Asbestos was not identified in within any of the 15 samples screened. Soil leachate analysis were undertaken on four samples including BH2059 - 1.0-1.1m begl in Lowestoft Formation, and leachate data for three samples obtained from eluate analysis (2:1) part of the WAC results -	Made Ground/Natural Reworked Ground was encountered in 29 of the positions investigated. The Made Ground primarily consisted of sandy gravely CLAY with brick and ceramics. 49 No. samples were tested comprising Made Ground (14), Made Ground/Natural reworked (one), Glaciofluvial (one) and Lowestoft (33). Concentrations for all determinands fell below the generic screening criteria for soils (no exceedances). Asbestos was not identified within any of the 49 samples sent for laboratory analysis. Suspected ACM in the form of asbestos cement sheet and other waste materials were encountered within 1.0m begl in an infilled area located to the southeast of this BP. Further investigation of this location was stopped (due to access permission issues). Soil leachate analysis were undertaken on 16 of the 49 samples. Concentrations of bioavailable

	BP-E	BP-F	BP-I	BP-J
	concentration of leachable copper above the EQS of 1 µg/l in BH2031 and TP1788.		TP1842 in Head Deposits at 0.40 – 0.50m begl, TP1843 in Made Ground/ Reworked Natural Deposits at 0.10 – 0.2m begl, BH2060 in Made Ground/ Reworked Natural Deposits at 0.70 – 0.80m begl. All determinands tested below the generic screening criteria for soils except a concentration of total cyanide in BH2059 in the Lowestoft Formation – 1.1ug/l marginally exceeded the EQS of 1ug/l.	lead in TP1861 - 2.40-2.50m begl in Glaciofluvial Deposits (2.05 µg/l), TP1861 - 0.0 - 0.10m begl in Made Ground/ Reworked Natural Deposits (1.90 µg/l), TP1875 - 0.1-0.2m begl in Made Ground (2.08 µg/l) and TP1854 - 0.1-0.2m begl in Made Ground (1.33 µg/l) exceed the EQS of 1.2 µg/l. Concentration of total cyanide in TP1875 (31 µg/l) exceed the EQS of 1 µg/l. Concentration of mercury in BH2072-0.50-0.60m begl in Head Deposits exceeds the DWS of 1 µg/l.
Ground Investigation Findings relative to Land Contamination - Groundwater	**Encountered Groundwater Conditions:** Based on the latest Phase 1 groundwater monitoring report dated November 2021, BH2027, BH2028, BH2029, BH2031 were sampled for laboratory testing on 18 June 2020 (Round 1 or R1), 15/07/2020 (Round 2 or R2) and 19 August 2020 (Round 3 or R3). The laboratory results showed the following exceedances: concentrations of nitrate (NO_3) in all locations exceed the DWS of 50mg/l (all three rounds). In BH2027, concentrations of nitrite as NO_2 (910 µg/l) exceeds the DWS (500 µg/) during monitoring round 1, concentration of manganese in this borehole was recorded above the DWS (50 µg/l) in all three monitoring rounds, with the value decreasing from 310 to 61 µg/l over 2 months. The response zones for all the wells sampled are: • BH2027: Lowestoft Formation (7.0 -18.8m begl) and London Clay (18.8-20m begl). • BH2028: Lowestoft Formation 5.80 - 8.70m begl, Glaciofluvial Deposits 8.70 - 16.20m, London Clay Formation 16.20 - 17.80m begl. • BH2029: Glaciofluvial Deposits 5.00 - 12.90m begl, London Clay Formation 12.90 - 14.00m begl. • BH2030: Glaciofluvial Deposits 7.20 - 13.70mbgl, Lowestoft Formation 13.70 - 14.50m begl, London Clay Formation 14.50 - 19.50m begl. • BH2031: Lowestoft Formation 5.00 -7.90m begl, Glaciofluvial Deposits 7.90 - 8.70m	**Encountered Groundwater Conditions:** Based on the latest Phase 1 groundwater monitoring report dated November 2021, two rounds of groundwater sampling for laboratory analysis were undertaken in BH2035 - 23 July 2020 (R1) and 08 October 2020 (R2) while three rounds of sampling were undertaken in BH2038 - 23 July 2020 (R1), 20 August 2020 (R2) and 19 October 2020 R3). In BH2038 concentrations of various determinands were recorded above their respective DWS and EQS including sulphate and nitrite NO_2 in R1 and sulphate and bioavailable copper in R2. Round 3 saw a number of exceedances including sulphate, nitrite, arsenic, cadmium, chromium (III), copper, lead manganese, nickel and zinc. The response zones for all the wells sampled are: • BH2035 - Made Ground 1.00 - 1.20m begl, Head Deposits 1.20 - 4.00m begl, London Clay Formation 4.00 - 4.50m begl • BH2036 - Brickearth 1.50 - 2.25m begl, London Clay 2.25 - 3.50m begl • BH2038 - Lowestoft Formation 2.00 - 7.00m begl	**Encountered Groundwater conditions:** Based on the latest Phase 1 groundwater monitoring report dated November 2021, BH2056, BH2058 and BH2059 were sampled on three occasions on 18 June 2020, 18 August 2020 and 19 November 2020. BH2059 was sampled on 07 July 2020, 05 August 2020 and 28 August 2020. BH2054 was sampled once on 21 January 2021. All samples were sent to the laboratory for chemical analysis. The following exceedances of the relevant screening criteria for controlled waters were recorded: • BH2054 – concentrations of nitrate as NO3 (101.4 4 mg/l) and sulphate as SO4 (271 mg/l) exceed their respective DWS of 50 mg/l and 250 mg/l. • BH2056 – concentrations of nitrate as NO3 (113. 4mg/l) and nitrite as NO2 (1150 µg/l) exceed the DWS in R1. Total cyanide (82 µg/l) exceeds the EQS of 1 µg/l and nitrate as NO3 (77.9mg/l) exceeds the DWS. • BH2059 – concentrations of ammoniacal nitrogen in R1 and R2 - 660 and 510 µg/l respectively exceed the EQS of 500 µg/l. concentrations of chloride - 290 and 260 mg/l in R1 and R2 exceed the EQS (250mg/l) and Total cyanide (3.4 µg/l) exceeds the EQS in R2. • The bioavailable concentration of copper (1.17 µg/l recorded in BH2059 in R3 marginally exceeds the EQS 1 µg/l.	**Encountered Groundwater Conditions:** Based on the latest Phase 1 groundwater monitoring report dated November 2021, BH2073 borehole was sampled for laboratory testing three times on 20 April 2020, 06 August 2020 and 07 September 2020. Groundwater levels in BH2065, BH2066 and BH2073 were measured prior to collection of groundwater. Both BH2065 and BH2066 were recorded to be dry whereas BH2073 contained water at 2.50m begl. Concentrations of nitrate as NO3 (74.0, 98.8 and 68.6mg/l) in all three rounds exceed the DWS (50 mg/l). Groundwater is expected to be shallow at this location - 2.50m begl within the Lowestoft formation but mostly dry. The response zones for all the boreholes sampled and tested are: • BH2065 - Head Deposits 1.00 - 1.65m begl, Glaciofluvial Deposits 1.65 - 9.20m begl • BH2066 - Lowestoft Formation 1.00 - 5.00m begl, Glaciofluvial Deposits 5.00 - 9.50m begl • BH2073 - River Terrace Deposits 1.00 - 6.20m begl, London Clay Formation 6.20 - 6.50m begl .

	BP-E	BP-F	BP-I	BP-J
	begl, London Clay Formation 8.70 - 9.00m begl. .		The response zones for all the boreholes sampled and tested are: • BH2056 - Head Deposits 1.00 - 2.00m begl, Glaciofluvial Deposits 2.00 - 2.70m begl • Lowestoft Formation 2.70 - 6.00m begl, London Clay Formation 6.00 - 6.50m begl • BH2058 - River Terrace Deposits 4.50 - 7.30m begl, London Clay Formation 7.30 - 8.00m begl • BH2059 - Lowestoft Formation 1.00 - 10.00m begl	
Preliminary Waste Classification The waste classification is only relevant if unsuitable materials (Class U1A, Class U1B, Class U2) are encountered during excavations requiring disposal to landfill.	Preliminary waste classification was undertaken using the first stage HazwasteOnline assessment which is based on the chemical analysis data for all the 15 samples tested. The results indicate that all samples are non-hazardous. The second stage WAC tests were undertaken on four. samples. Two samples were below "Inert" WAC (BH2026 in silt at 0.30-0.50m begl; TP1788 in silt at 0.80-1.00m begl) and 2 No. (BH2031 in clay at 0.60-0.70m begl; TP1777 in clay at 1.40–1.50m begl) are not considered inert.	Preliminary waste classification was undertaken using the first stage HazwasteOnline assessment which is based on the chemical analysis data for all the 14 samples tested. The results indicate that all samples are non-hazardous. The second stage WAC tests were undertaken on four samples - (BH2032 in Made Ground at 0.20-0.40m begl, BH2037 in clay at 0.50 – 0.70m begl, TP1794 in Made Ground/Natural Reworked Deposits at 0.20 – 0.30m begl, TP1803 in clay at 1.20 – 1.70m begl). All four samples are not inert.	Preliminary waste classification was undertaken using the first stage HazwasteOnline assessment which is based on the chemical analysis data for all the 15 samples tested. The results indicate that all samples are non-hazardous. The second stage WAC tests were undertaken on three samples. TP1842 in clay at 0.40 – 0.50m begl classified as inert. TP1843 in clay at 0.10 – 0.2m begl, BH2060 in silt at 0.70 – 0.80m begl are not inert.	Preliminary waste classification was undertaken using the first stage HazwasteOnline assessment which is based on the chemical analysis data for all the 49 samples tested. The results indicate that all samples are non-hazardous. The second stage WAC tests were undertaken on 14 samples including TP1861 (2), TP1880, TP1860, TP1877, TP1879, TP1867, TP1869, BH2073, TP1872, TP1875, BH2068, BH2069 and BH2067. The samples were taken from depths ranging from 0.00m begl to 1.20m begl. Three of the above samples were taken from Made Ground, three were taken from Topsoil, six were taken from the Lowestoft Formation and the remainder were taken from the River Terrace Deposits. Six samples were recorded as 'Inert' the other eight samples were not inert.
Material Suitability Assessment	**Class U1B (contaminated soils above the generic screening criteria for soils -** None identified **Class U2 (Hazardous material) -** None identified.	**Class U1B (contaminated soils above the generic screening criteria for soils -** None identified **Class U2 (Hazardous material) -** None identified.	**Class U1B (contaminated soils above the generic screening criteria for soils -** None identified **Class U2 (Hazardous material) -** None identified.	**Class U1B (contaminated soils above the generic screening criteria for soils -** None identified **Class U2 (Hazardous material) -** None identified from all the samples tested. However, asbestos containing materials may be exposed if the infilled land area is disturbed during construction of the proposed scheme.

Soil chemical quality assessment

6.9.3 As part of the ground investigation, a total of 93 soil samples (BP-E (15), BP-F (14), BP-I (15) and BP-J (49) were scheduled for chemical analysis for a range of suites (see Table 4.4) to obtain information on the chemical quality of the soils likely to be encountered during works. This also enabled the assessment of potential risk to human health receptors identified at the borrow pit sites. Samples analysed were selected from various depths targeting mainly Made Ground and other materials where there was visual or olfactory evidence of contamination.

Soil data screening against generic screening criteria for human health risk assessment

6.9.4 All the total concentrations of substances in the soil samples tested were screened against the generic screening criteria for soils applied in the assessment of risks to human health from exposure to any contamination in soil (see Section 5.5 of this report for details of the generic screening criteria used). Given the end use of the borrow pits materials for construction of a highway scheme, the commercial / industrial screening criteria were adopted.

6.9.5 Based on the screening results, all the soil samples recorded concentrations of all the determinands tested below the generic screening criteria for soils. The screening results are summarised in Table 6.2.

Asbestos

6.9.6 Asbestos was not identified in all the 93 samples screened in the laboratory for presence of asbestos. However, suspected ACM in the form of asbestos cement sheet and other waste materials were encountered in BP-J during the GI within 1.0m begl in an infilled area located to the southeast of the borrow pit. Further investigation of this location was stopped (due to access permission issues).

Preliminary waste soil assessment

6.9.7 Current regulations require that the disposal of construction waste to landfill is minimised. However, should any soils require disposal off site, the preliminary waste classification is a two-stage process. The first stage is the HazWaste Online classification which provides an assessment to classify soil arisings from the borrow pits as either as hazardous or non-hazardous. The second stage – WAC testing is used to determine the suitable landfill type for any excess or unsuitable materials. The WAC results are screened against acceptance criteria for three landfill types – inert landfill, stable non-reactive hazardous waste in non-hazardous landfill and hazardous waste landfill.

6.9.8 A preliminary waste classification was undertaken for all the 93 soil samples that were subjected to laboratory chemical analysis, using HazWaste Online, a programme which enables waste characterisation of soil based on the chemical analysis in accordance with the Environment Agency guidance, ‘Hazardous Waste: Interpretation of the definition and classification of hazardous waste, Technical Guidance WM3’ (2021) (Reference 14). This enables the classification of each sample as either hazardous (European Waste Catalogue

(EWC) Code 17-05-03) or non-hazardous (EWC Code 17-05-04). HazWaste Online draws its results from an algorithmic model that is based on a number of conservative assumptions.

6.9.9 The waste classification undertaken indicate that all the samples tested would classify as non-hazardous. The results of this assessment for each of the borrow pit sites are summarised in Table 6.2.

Landfill waste acceptance criteria (WAC) assessment

6.9.10 WAC testing is used in addition to the Preliminary Waste Classification to further determine the suitable landfill type should disposal of waste soil to landfill be considered during the proposed A12 scheme development. This testing comprises a soil leachate suite and a solid suite i.e. total. WAC testing was undertaken on a total of 26 samples selected from each of the four borrow pits (BP-E (4) BP-F (4) BP-I (3) BP-J (14).

6.9.11 Based on the WAC results, majority of the samples tested may be suitable for a non-hazardous waste landfill. A small number of the samples collected mainly from natural ground were considered inert. of the samples. Table 6.2 provides a summary of the exploratory hole locations assessed as inert.

Ground gas monitoring

6.9.12 In the majority of the borrow pits' locations, potential sources of ground gases including historical landfill sites, infilled land associated mainly with historical ponds were identified on and in close proximity to the sites.

6.9.13 Gas monitoring standpipes were installed in selected locations with screening zones targeting mainly made ground. Six weekly ground gas monitoring rounds were undertaken post ground investigation to provide information on ground gas regime within these borrow pits and also to enable assessment of potential risks to human health.

6.9.14 The monitoring was undertaken by the GI contractor. Measurements of ground gas flow, atmospheric pressure, concentrations of methane, carbon dioxide, oxygen, volatile organic compounds and groundwater level were undertaken approximately weekly for six weeks during spring and summer 2020.

6.9.15 The number of exploratory holes monitored for each borrow pit and the results of the field monitoring are presented in Table 6.3 below.

Table 6.3 Borrow pits ground gas monitoring results and hazardous gas risk assessment

Borehole ref.	Flow rate (l/hr)		Methane (% v/v)		Carbon dioxide (% v/v)		Oxygen (% v/v)		VOCs (ppm)		Water level range (m bgl)	Atmospheric pressure (mbar)
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
Borrow pit E												
BH+RC1110	0.0	16.0	-0.3	-0.1	<0.1	0.7	19.3	21.1	0.0	3.4	0.00	1001 - 1024
Borrow pit F												
BH2038	0.0	0.0	-0.2	-0.1	0.1	1.7	16.8	20.4	0.0	11.0	4.95 - 6.39	1001 - 1020
BH2042a	0.0	0.0	-2.6	-0.1	<0.1	1.6	15.7	20.4	0.0	1.8	2.90 - 3.35	1005 - 1026
BH2043	0.0	0.0	-0.2	0.0	<0.1	0.7	13.6	20.8	0.0	30.1	3.43 - 6.54	1004 - 1024
BH2044	0.0	0.0	-0.3	0.0	<0.1	5.3	5.9	21.0	0.0	17.8	1.99 - 2.54	1003 - 1024
BH2045	-24.1	32.4	-0.3	0.0	<0.1	3.5	11.9	20.8	0.0	15.1	1.07 - 1.51	1001 - 1023
BH2046	-0.1	0.0	-0.2	-0.1	<0.1	4.6	7.0	20.9	0.0	17.0	1.29 - 1.50	1006 - 1021
Borrow pit I												
BH2058	-1.1	1.2	-0.9	0.2	<0.1	0.9	19.4	20.9	0.0	17.2	0.80 - 1.22	1004 - 1019
BH2059	0.0	6.77	-0.5	-0.1	0.3	2.1	18.6	21.0	0.0	17.1	1.56 - 3.70	1003 - 1020
Borrow pit J												
BH2066	-6.1	9.7	-0.3	0.0	0.4	2.2	12.8	19.3	0.2	5.4	9.25 - >9.50	1002 - 1025
BH2073	-3.4	0.0	-0.3	0.0	0.4	2.0	17.8	20.1	0.0	0.6	2.05 - 2.26	1008 - 1026

Ground gas risk assessment

6.9.16 Concentrations of methane were recorded below the lower explosive limit (LEL) of 5% volume/volume (v/v) in all the borrow pit locations monitored.

6.9.17 Elevated flow rates were recorded in borrow pits E, I and J. These are attributed to peak flow on opening the gas tap and do not represent continuous steady flow rates from the standpipes which were all at or close to zero.

6.9.18 On at least one monitoring occasion, negative flow rates were recorded, this is an effect of high atmospheric pressure at the time of monitoring.

6.9.19 The ground gas risk assessment undertaken shows that the majority of the borrow pits have low gas generating potential in the monitored location. During the proposed material excavation works in the borrow pits, method statements and risk assessment for gas monitoring in excavations should be undertaken in accordance with HSE (2013) RR973: Review of alarm setting for toxic gas and oxygen detectors.

Soil leachability assessment

6.9.20 As part of the ground investigation, soil samples retrieved from the borrow pits were scheduled for soil leachability analysis to assess the potential for the soil within the borrow pits to act as a source of contamination to groundwater and surface water when placed on the proposed scheme. The analysis is based on BS - 12457-1, a single stage leaching process at a liquid: solid ratio of 2:1. The analytical results were compared against EQS (annual average values). Where the EQS is not available, the more conservative DWS criteria have been applied.

6.9.21 A total of 24 soil leachate samples (borrow pit E (four), borrow pit F (three), borrow pit I (four) and borrow pit J (16) were analysed. The concentrations of the determinands recorded in most of the samples exceed the relevant screening criteria for controlled waters. The results are summarised in Table 6.2.

6.9.22 It is intended that materials from the borrow pits would be utilised in the construction of the proposed scheme. Materials to be moved to the proposed scheme as fill materials for permanent works may pose risks to nearby surface water and groundwater underlying the proposed scheme if leachable contaminants are present.

6.9.23 Prior to placing materials on the proposed scheme, further assessment of risks to sensitive controlled waters at the receiving location should be undertaken.

Groundwater quality assessment

6.9.24 Assessment of the potential risk to groundwater underlying the borrow pit sites during the excavation of the proposed scheme has been undertaken by screening the chemical analysis results against the relevant screening criteria for controlled waters (see Section 5.5 of this report).

6.9.25 In the UK, the appropriate screening criteria adopted for assessment of risks to groundwater from land contamination is usually dependent on the relevant controlled waters receptors. For the borrow pit sites, Secondary A and Secondary Undifferentiated aquifers have been identified within the superficial deposits. Also, a number of surface water bodies including main rivers which maybe hydraulically connected with the groundwater beneath the borrow pit sites have also being identified as receptors.

6.9.26 Based on the controlled water receptors identified, groundwater monitoring wells were installed to monitor groundwater levels within each of the borrow pits to enable sampling for contamination analysis and establish baseline groundwater conditions which will be used to identify changes to groundwater quality during and post excavation works. The response zones for each of the wells sampled for chemical analysis are summarised in Table 6.2.

6.9.27 A total of 10 groundwater wells (borrow pit E (four), borrow pit F (two), borrow pit I (three) and borrow pit J (one) were samples and analysed for a range of determinands over three monthly sampling visits. Some of the locations were sampled only on two visits because of the wells being dry at the time of visit. Only one well had water in borrow pit J during all three visits. At least one borehole within each of the borrow pits recorded concentrations of some of the

determinands above the relevant screening criteria for controlled waters indicating a generally poor groundwater chemical quality across all the borrow pits. The screening results are summarised in Table 6.2.

Material suitability assessment

6.9.28 The anticipated stratigraphy at the borrow pits and the material suitability assessment for each of the borrow pits is summarised in Table 6.2.

6.9.29 Near surface soils typically between 0-0.3mbgl (possible topsoil) on each of the borrow pit sites may be classified as Class 5A material (topsoil, or turf, existing on site) for re-use on the proposed scheme subject to the Definition of Waste (2011), DoWCoP. This should be stripped prior to excavation and retained for re-use as topsoil and landscaping after the construction of the earthworks.

6.9.30 All the soil samples tested (including Made Ground and natural ground) recorded concentrations of all the determinands tested below the generic screening criteria for soils and could be used during construction of the proposed scheme subject to DoWCoP.

6.9.31 All the soil materials tested are non-hazardous and may be suitable for a non-hazardous waste landfill if offsite disposal of excess or unsuitable soils are considered.

6.9.32 Class U2 materials (hazardous materials) were not identified in any of the samples tested. However, an area of infilled land was identified within borrow pit J during the current Phase I GI. A trial pit investigation was attempted but was stopped by the landowner at 1mbgl (due to access permission issues). This limited investigation revealed the presence of suspected ACMs – asbestos cement sheets and other waste materials. It is anticipated that any excavation works in this area may expose potentially contaminated materials and asbestos. Isolation of the area during excavation works is required to avoid exposing ACMs to the surface. This area is shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].

6.9.33 Chemical analysis carried out on soils during the ground investigation recorded concentrations of various substances tested below the generic screening criteria for soils. It is possible however that excavation works may expose unacceptable contaminated material not identified in the ground investigation; therefore, a watching brief should be maintained during the works.

6.10 Borrow pits updated conceptual site model

6.10.1 The preliminary CSM and risk assessment undertaken as part of the PSSR have been re-evaluated following the ground investigation based on the Environment Agency LCRM guidance.

6.10.2 Potential risks to human health have been assessed using the CSM and screening soil contaminant concentrations against the generic screening criteria for soils. Similarly, potential risks to controlled waters have been assessed using the CSM and screening the groundwater and soil leachate analysis results against relevant screening criteria for controlled waters. The updated CSM and risk assessment based on GI findings is summarised in Table 6.4 below.

Table 6.4 Borrow pits updated CSM and risk assessment

Potential land contamination sources (on and within 250m)	Potential pathways	Receptors
Borrow pit E		
Potential onsite sources of land contamination identified: Made ground encountered on site in some of the exploratory holes during all the GIs (possibly associated with a historical pond and a small structure next to the pond). All the soil samples tested recorded concentrations of all the determinands below the generic screening criteria for soils. Potential agricultural use of pesticides and herbicides on site (groundwater chemical analysis results recorded nitrate in groundwater above the relevant screening criteria for controlled waters.	Direct contact, inhalation and ingestion of soils by construction workers.	Construction workers (negligible impact anticipated). Potential low impact anticipated if unknown contaminated materials are uncovered during construction of the proposed scheme.
	Inhalation of fugitive dusts by users in nearby areas during construction.	Offsite users during construction of the proposed scheme (negligible impact anticipated).
	Leaching of contaminants from soils via rainwater infiltration (elevated levels of bioavailable copper are recorded above EQS in two soil leachate samples).	Groundwater within the superficial deposits underlying the borrow pit: Glaciofluvial Deposits – Secondary A aquifer. Head Deposits and Lowestoft Formation - Secondary Undifferentiated aquifer.
		Groundwater underlying the proposed scheme where the soil material from the borrow pit would be placed and possible migration to surface waters surrounding the proposed scheme.
	Runoff from soils stockpiled during excavation works to surrounding surface waters on and within 250m.	Pond located on the north-west quadrant of the site. Tertiary Watercourse at 120m south.
Offsite sources below are considered valid as elevated concentrations of several substances were recorded in groundwater above screening criteria. Potential groundwater contamination associated	Vertical and lateral migration of contaminants in groundwater.	Groundwater within the superficial deposits: Glaciofluvial Deposits – Secondary A aquifer. Head Deposits and Lowestoft Formation - Secondary Undifferentiated aquifer. Groundwater abstraction 'Churches Nursery abstraction' approximately 130m east of the site.

Potential land contamination sources (on and within 250m)	Potential pathways	Receptors
with the railway embankment approximately 50m north. Potential fuel leaks / spills deriving from the used car dealership 50m to the south-east and potential use of pesticides and herbicides associated with the historical nursery at the site.		Two PWSs to the east of the BP, approximately 100m and 200m from the proposed scheme boundary.
	Migration of contaminants from groundwater to offsite surface waters within 250m via base flow. Discharge of pumped contaminated water to surface water during dewatering.	Tertiary Watercourse at 120m south.
Borrow pit F		
Potential on-site sources of land contamination identified are: Made ground encountered on site (possibly associated with a historical track on site). All the soil samples tested recorded concentrations of all the determinands below the generic screening criteria for soils. Potential agricultural use of pesticides and herbicides on site (groundwater chemical analysis results recorded nitrate above the relevant screening criteria for controlled waters).	Direct contact, inhalation and ingestion of soils by construction workers.	Construction workers (negligible impact anticipated). Potential low impact anticipated if unknown contaminated materials are uncovered during construction of the proposed scheme.
	Inhalation of fugitive dusts by users in nearby areas during construction (pathway still valid).	Offsite users during construction of the proposed scheme (negligible impact anticipated).
	Leaching of contaminants from soils via rainwater infiltration (elevated concentrations of total cyanide recorded in one soil leachate sample).	Groundwater within the superficial deposits underlying the borrow pit: Glaciofluvial Deposits – Secondary A Aquifer. Alluvium – Secondary A Aquifer. Brickearth – Secondary B Aquifer. Lowestoft Formation – Secondary Undifferentiated.
		Groundwater and sensitive aquifers underlying the proposed scheme where the excavated soil material would be placed and possible migration to surface waters surrounding the proposed scheme.
	Runoff from soils stockpiled during excavation works.	Drainage ditch – southern periphery. Pond - 20m south-east.

Potential land contamination sources (on and within 250m)	Potential pathways	Receptors
		Pond -100m north-east.
Offsite sources identified are considered valid as elevated concentrations of several determinands are recorded above the relevant screening criteria for controlled waters in groundwater within the borrow pit. Potential groundwater contamination associated with a petrol filling station 100m to the north. Potential groundwater contamination associated agricultural use of pesticides and herbicides on adjacent land.	Vertical and lateral migration of contaminants.	Groundwater within the superficial deposits. Glaciofluvial Deposits – Secondary A Aquifer. Alluvium – Secondary A aquifer. Brickearth – Secondary B aquifer. Lowestoft Formation – Secondary Undifferentiated.
	Discharge of pumped contaminated water to surface water during dewatering. Migration of contaminants from groundwater to offsite surface waters within 250m via base flow.	Pond - 20m south-east. Pond -100m north-east.
Borrow pit I		
Potential on-site sources of land contamination identified are: Made ground encountered on site (possibly associated with the railway and road embankment which borders the north and south boundaries). All the soil samples tested recorded concentrations of all the determinands below the generic screening criteria for soils. Potential agricultural use of pesticides and herbicides on site (groundwater chemical analysis results recorded nitrate in groundwater above the relevant screening criteria for controlled waters).	Direct contact, inhalation and ingestion of soils by construction workers.	Construction workers (negligible impact anticipated). Potential low impact anticipated if unknown contaminated materials are uncovered during construction of the proposed scheme.
	Inhalation of fugitive dusts by users in nearby areas during construction.	Offsite users during construction of the proposed scheme (negligible impact anticipated).
	Leaching of contaminants from soils via rainwater infiltration (marginal exceedance of total cyanide concentration in one soil leachate sample).	Groundwater within the superficial deposits underlying the borrow pit: Head Deposits – Secondary Undifferentiated. Glaciofluvial Deposits – Secondary A Aquifer. Lowestoft Formation – Secondary Undifferentiated.
		Groundwater underlying the proposed scheme where the soil material would be placed and possible migration to

Potential land contamination sources (on and within 250m)	Potential pathways	Receptors
		surface waters surrounding the proposed scheme.
	Runoff from soils stockpiled during excavation works (as well as silt).	Minor watercourse along southern boundary. Spring: 60 m south-west, 110 m south-west and 120 m south-east. Rivenhall Brook: 60 m south west.
Offsite sources are considered valid as elevated concentrations of several determinands were recorded in groundwater within the borrow pit above the relevant screening criteria for controlled waters. Potential groundwater contamination associated with the railway embankment and A12 road embankment at 20m north and south respectively. Potential groundwater contamination associated with car dealership and obsolete petrol station at 120m to the south.	Vertical and lateral migration of contaminants in groundwater.	Groundwater within the superficial deposits underlying the borrow pit: Head Deposits – Secondary Undifferentiated. Glaciofluvial Deposits – Secondary A Aquifer. Lowestoft Formation – Secondary Undifferentiated.
	Migration of contaminants from groundwater to offsite surface waters within 250m via base flow.	Springs at 60m south, 110m south and Rivenhall Brook at 60m south-west.
Borrow pit J		
Onsite sources of land contamination: Made ground encountered on site in other locations (possibly associated with dismantled railway crossing the site and historical infilled pits). All the soil samples tested recorded concentrations of all the determinands below the generic screening criteria for soils. Potential agricultural use of pesticides and herbicides on site.	Direct contact, inhalation and ingestion of soils by construction workers (pathway still valid).	Construction workers (negligible impact anticipated). Potential low impact anticipated if unknown contaminated materials are uncovered during construction of the proposed scheme.
	Inhalation of fugitive dusts by users in nearby areas during construction (pathway still valid).	Offsite users during construction of the proposed scheme (negligible impact anticipated).
	Leaching of contaminants from soils via rainwater infiltration (elevated	Groundwater within the superficial deposits underlying the borrow pit: Head Deposits – Secondary Undifferentiated.

Potential land contamination sources (on and within 250m)	Potential pathways	Receptors
	concentrations of several contaminants were recorded above the relevant screening criteria for controlled waters in the soil leachate samples tested).	Glaciofluvial Deposits and River Terrace Deposits – Secondary A Aquifer Lowestoft Formation – Secondary Undifferentiated.
		Groundwater SPZ zone 3 (total catchment) situated in the eastern half of the site.
		Groundwater underlying the proposed scheme where the soil material would be placed and possible migration to surface waters surrounding the proposed scheme.
	Runoff from soils stockpiled during excavation works.	Pond on the western quadrant of site Ponds at 80m north-east, 150m south-east and 70m north-east of eastern Borrow Pit boundary (in adjacent property). Domsey Brook at 150m north. Watercourse at 115m east.
Onsite sources Suspected ACMs encountered in historical infilled land to the south-west of the site. Presence of asbestos fibres in this location has not been confirmed as detailed GI has not been undertaken. Isolation of the area during works should be adopted	Inhalation of asbestos fibres if ground is disturbed Potential health impact.	Construction workers
Onsite sources Ground gases associated with pockets of infilled land within the site Methane levels recorded in monitored boreholes were below the 5% v/v lower explosive limit (LEL).	Inhalation of toxic ground gases in confined space could lead to asphyxiation.	Construction workers

Potential land contamination sources (on and within 250m)	Potential pathways	Receptors
Offsite sources (only limited groundwater testing data is available at the time of reporting. Data from one sample recorded nitrate in groundwater above the relevant screening criteria for controlled waters. Potential groundwater contamination associated with farms yards and car parks adjacent to site. Potential groundwater contamination associated with historical infilled mineral extraction pits located to the north-east and north-west boundaries of the site.	Vertical and lateral migration of contaminants in groundwater.	Groundwater within the superficial deposits underlying the borrow pit

6.11 Land contamination assessment summary and recommendations

6.11.1 The following recommendations should be adopted for all borrow pits:

6.11.2 Chemical analysis of soil samples undertaken as part of the site-specific intrusive GI indicates that all the determinands tested are below the generic screening criteria for soils appropriate for the assessment of risk to human health from a commercial / industrial end use. Therefore, soils excavated from the borrow pits could be used during construction of the proposed scheme subject to DoWCoP.

6.11.3 It is anticipated that the excavation of the borrow pits may expose contaminated material not identified in the GIs. A watching brief should therefore be maintained during excavation and if potentially contaminated material is identified then it should be assessed in place (tested to determine suitability for reuse or for offsite disposal to landfill) without being excavated (if possible). Excavation and stockpiling should only be used if it is not possible to assess the material in place. This is to avoid excess disposal costs.

6.11.4 Groundwater underlying all the borrow pits and surrounding areas recorded some contaminants above the relevant screening criteria for controlled waters indicating generally poor chemical quality. Uncontrolled discharge of water to surrounding areas during dewatering should be avoided. Any discharge to surrounding surface water would be under a permit or discharge consent. Further Detailed Quantitative Risk Assessment (DQRA) is required for the management of any dewatering and to support a permit for discharge.

6.11.5 The ground gas risk assessment undertaken shows that the majority of the borrow pits have low gas generating potential in the monitored location. Proposed material excavation works are not likely to create confined spaces. When working in excavations, method statements and risk assessment for gas monitoring in excavations should be undertaken in accordance with HSE (2013) RR973: Review of alarm setting for toxic gas and oxygen detectors.

6.11.6 Preliminary waste assessment using HazwasteOnline confirmed that all the soil samples tested are non-hazardous but not considered inert in most locations (based on WAC assessment). If waste disposal is required, further assessment of the soils should be undertaken to delineate areas of potentially inert material and appropriate segregation measures should be taken.

6.11.7 Soil leachability analysis data confirmed that leachable contaminants are present in various strata (Made Ground, Reworked Natural Deposits, Lowestoft Formation, Head Deposits and Glaciofluvial Deposits) across all borrow pits in some of the samples tested. Soils in the locations tested are considered to be potential source of groundwater contamination. Detailed Quantitative Risk Assessment (DQRA) will be required to determine suitable acceptability criteria prior to placing materials excavated from all the borrow pits on the proposed scheme particularly in locations where sensitive aquifers are present or near surface water courses.

6.11.8 In general, exposure of construction workers to any unknown contamination in soil or contaminated water encountered during excavation of the borrow pits can be mitigated by the adoption of good working practices suited for construction including the use of PPE. However, ACMs may be exposed in borrow pit J if the known area of infilled land is disturbed during works. This area is shown on Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].

6.12 Risk register

6.12.1 The scoring system used in the borrow pits geo-environmental risk register is shown in Tables 5.21, 5.22, 5.23, 5.24 in Section 5.6 of this report. The borrow pits geo-environmental risk register is shown in Table 6.5.

Table 6.5 Borrow pits geo-environmental risk register

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
GEO ENVIRONMENTAL											
1	Exposure of construction workers and nearby site users to potentially contaminated soils associated with on-site land uses and proximal off-site historical land uses.	Proposed borrow pit excavation works are likely to expose any contamination within the soil to the surface.	4	3	12	Health impact to construction workers. Programme delays and additional costs to undertake clean-up if contamination in soil is at levels above the generic screening criteria for soils.	Chemical testing of soil samples undertaken as part of the site-specific intrusive GIs indicates that recorded levels of all determinands tested are below the generic screening criteria for soils.	1	3	3	Good working practices appropriate for a construction site should be implemented during works including the use of PPE to reduce workers exposure to soils, and the use of dust suppression measures to prevent exposure of both onsite and offsite users to potentially contaminated windblown dust during works.
2	Encountering potentially contaminated soils in the borrow pits during excavation works.	Potential to uncover potentially contaminated materials not identified during the GI works	3	3	9	Restriction on reuse of soils excavated from the borrow pits. Possible waste disposal costs and re-sourcing of alternative materials. Delays to programme.	Watching brief method of working is required during excavation works. Suspected contaminated materials to be segregated to avoid cross contamination. Sampling and laboratory analysis should be undertaken to determine suitability for reuse or disposal option. If possible, suspected contaminated materials should be assessed in place without being excavated to avoid excess disposal costs. Also, assessment of risks to workers from exposure to the materials should be undertaken.	1	3	3	Contractor to produce a contamination response protocol in the event that potentially contaminated materials, including asbestos and ACM are encountered during works.
3		Proposed excavation works at borrow pit J is likely to locally expose ACMs and other contaminated materials.	3	5	15	Health impact to construction workers is anticipated. Possible inhalation of asbestos fibres if suspected asbestos containing ground is disturbed during works. Programme delays and additional costs to undertake clean-up if contamination in soil is at levels above the generic screening criteria for soils.	Limited trial pitting of an area of historical infilled land revealed the presence of suspected asbestos cement sheets and other waste materials. The presence of asbestos fibres has not been confirmed. Based on the preliminary risk assessment undertaken, suspected ACM underlying the site is unlikely to pose any risk to human health if undisturbed. Therefore, disturbance of this area should be avoided during all proposed works and that the area be isolated. The location of the infilled ground has been identified on the Land Contamination Constraints Plan, Figure 10.1 of the Environmental Statement [TR010060/APP/6.2].	1	5	5	Location of potential asbestos hazard should be indicated on all site work drawings for this site. Contractor to produce a contamination response protocol should asbestos, suspected ACM or other potentially contaminated materials be encounter during works.

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
4	Contamination of groundwater	Potential for contaminants associated with offsite sources of land contamination identified in close proximity of the borrow pits (including hydrocarbons from petrol station, leachates from historical landfills, historical infilled gravels pits and ponds) to be drawn into the groundwater underlying the borrow pits via pathways created by excavation works. Leaching of contaminants from soils via rainwater infiltration and migration of contaminants in groundwater.	4	3	12	Contamination of groundwater including sensitive aquifers within shallow superficial deposits Potential clean-up costs and project delays if impacted	Baseline testing of groundwater conditions across the borrow pits undertaken as part of the site-specific GI, indicate that groundwater underlying all the borrow pits have already been impacted as concentrations of various substances were recorded above the relevant screening criteria for controlled waters. This is likely associated with onsite land uses and offsite sources of land contamination identified. Further DQRA is required for the management of any dewatering and to support a permit for discharge. There is potential for further migration of contaminants during works via pathways created by excavation works. Adequate control measures (as recommended in C648) should be adopted during proposed works. Additional groundwater monitoring and chemical analysis should be undertaken to confirm the initial works and identify changes to water quality before, during and post construction.	2	3	6	Groundwater management plan to be produced and implemented as part of second iteration of the EMP to prevent pollution of the secondary aquifer underlying the borrow pit sites. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted during the excavation of the borrow pits.
		Placement of fill materials containing leachable contaminants in sensitive locations on the proposed scheme.	3	3	9	Leaching of contaminants from soil placed on the proposed scheme into groundwater and possible migration to surface waters. Contamination of sensitive aquifers and surface waters Potential clean-up costs, fines and project delays if impacted.	Soil leachability analysis and screening of the laboratory results have been undertaken as part of the Phase 1 GI. Leachable substances were recorded above the relevant screening criteria for controlled waters in most of the samples collected from all the borrow pits. Any fill materials to be used on the proposed scheme should be determined suitable for reuse by the adoption of an appropriate acceptability criterion derived from a DQRA.	1	3	3	Groundwater and surface water management plan to be produced and implemented as part of the second iteration of the EMP to prevent pollution of sensitive aquifers underlying the proposed scheme where the material would be placed and local surface waters receiving baseflow. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted.

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
		Migration of contaminants in groundwater to offsite Anglian Water public water supply abstraction at 160m north-west of borrow pit J via pathways created during works (note that the distance is now 500m based on DF3.0 model)	3	4	12	Contamination of licenced public potable water supply abstraction. Potential clean-up costs, fines and project delays if impacted.	The site-specific GI has identified some soil leachability results to be above the relevant screening criteria for controlled waters indicating poor chemical groundwater quality beneath the proposed pit. Since the abstraction is used for public drinking water supply, it is likely that the source is the Chalk, which is protected by the overlying low permeability London Clay, and therefore the risk would be very low. However, consultation with the abstraction owner should be undertaken to obtain abstraction details including if it is still in use and the source. Information obtained will be used to refine the risk assessment in consultation with the Environment Agency (if required).	1	4	4	Groundwater management plan to be produced and implemented as part of the second iteration of the EMP to prevent pollution of the offsite licenced public water supply abstraction. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted.
		Migration of contaminants in groundwater to offsite licenced groundwater abstraction 'Churches Nursery abstraction' at 250m east of borrow pit E. Several other licenced groundwater abstractions located between 500m and 1km of all the borrow pits.	3	3	9	Contamination of licenced abstraction for agricultural use. Potential clean-up costs, fines and project delays if impacted.	Migration of contaminants in groundwater at the borrow pit sites to offsite abstractions located within 250m of; borrow pit E is considered possible however the majority of the abstractions are used for agricultural purposes. The potential impact is therefore anticipated to be low. Potential risk to other licenced groundwater abstractions located >500m from the borrow pits is anticipated to be low due to the distances to the receptors and dilution/natural attenuation factors.	1	3	3	
		Migration of contaminants in groundwater to offsite PWS abstractions to the east of the borrow pit E, approximately 100m and 200m from the proposed scheme's boundary. Several other PWS located between 500m and 1km of all the borrow pits.	3	3	9	Contamination of two private water supply abstractions (unknown use). Potential clean-up costs, fines and project delays if impacted.	Migration of contaminants in groundwater at BP-E to offsite PWS is considered possible, however, information on the source of both abstractions and their uses are not known at this stage. Consultation with the abstraction owner should be undertaken to obtain abstraction details in order to refine the risk assessment in consultation with the Environment Agency (if required). Potential risk to other PWS located >500m from the borrow pits is anticipated to be low due to the distance to the receptors and dilution/natural attenuation factors.	1	3	3	

	Risk / hazard	Cause	Before control			Consequence	Mitigation control measure taken by the designer	Residual risk			Preventive measures to control risk
			P	I	R			P	I	R	
5	Pollution of surface water near the borrow pit sites.	Direct run-off of contaminants and silt from stockpiled soils or excavation works to surface watercourses located adjacent to the borrow pits. Uncontrolled discharge of water pumped out from excavations during dewatering (groundwater at the borrow pit sites show poor chemical quality).	3	3	9	Pollution of surface water. Potential clean-up costs and project delays if impacted. Potential fines and prosecution. Possible high costs for pumped water desilting and treatment prior to discharge.	Excavated materials should be stored appropriately away from watercourses. The site-specific GI has identified some soil leachability results to be above the relevant screening criteria for controlled waters indicating poor chemical quality beneath the proposed pit. The uncontrolled discharge of groundwater associated with dewatering / ground water lowering associated with construction of the pit is likely to contaminate surrounding surface waters and should be avoided. Further DQRA is required for the management of any dewatering and to support a permit for discharge. Monitoring of all the surface watercourses on or close to the borrow pits to be undertaken to establish baseline conditions prior to works. Additional monitoring should be undertaken to identify changes to surface water quality during and post excavation works.	2	3	6	Surface water management plan should be produced in the second iteration of the EMP. Discharge to existing surface waters surrounding the borrow pits should be under the EA permit or discharge consent. Pollution prevention and control measures detailed in CIRIA C648 - Control of water pollution from linear construction projects should be adopted during construction
6	Hazardous ground gases on site associated with small pockets of historical infilled land within the borrow pits.	Pathways created by excavation works could cause ground gas migration into the excavation.	2	3	6	Exposure of construction workers to ground gases during excavation works. Inhalation of ground gases could lead to asphyxiation. Health impact issues.	Available ground gas monitoring data indicate that methane levels recorded in all the boreholes are below the lower explosive limit (LEL) of 5% volume/volume. Proposed works within the borrow pits would involve open excavation and therefore confined spaces are not likely to be created. Based on the monitoring results, low levels of ground gases are anticipated in the affected borrow pits and would likely vent into the atmosphere during works.	1	3	3	Risk can be mitigated by adhering to good working practices and confined spaces entry protocols. Method statements and risk assessment for gas monitoring in excavations should be undertaken in accordance with HSE (2013) RR973 - Review of alarm setting for toxic gas and oxygen detectors.

References

A12 Chelmsford to A120 Widening Scheme specific documents

British Geological Survey (1986). The Geology of the Country around Braintree, Sheet 223, Ellison.

British Geological Survey (1975).1:50,000 Sheet 241 Chelmsford (Solid and Drift Edition)

British Geological Survey (1982), 1:50,000 Sheet 223 Braintree (Solid and Drift Edition)

British Geological Survey (1985). The Geology of the Country around Chelmsford, Sheet 241, Bristow

Environmental Scoping Opinion Report (TR010060-000009-CHLM)

British Standard and Eurocodes

BS 8002:2015 Code of practice for earth retaining structures

BS EN 1997-2 Geotechnical Design – Ground Investigation and Testing

BS EN ISO 14688-2:2018 Geotechnical Investigation and Testing – Identification and Classification of Soil

The British Standards Institution (2011) BS 10175: Investigation of Potentially Contaminated Sites-Code of Practice.

National Highways

Highways Agency (1995) HA 44/91 Earthworks – Design and Preparation of Contract Documents

Other documents

Contaminated Land: Applications in Real Environments (CL: AIRE) (2011), The Definition of Waste, Development Industry Code of Practice version 2.

Environment Agency et al. (2018). Waste Classification, Guidance on the Classification and Assessment of Waste (Edition v1.1), Technical Guidance WM3. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/719394/Waste-classification-technical-guidance-WM3.pdf. Accessed December 2020

Environment Agency (2014). Regulatory position statement 075: The movement and use of treated asphalt waste containing coal tar. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/419686/LIT_10118.pdf. Accessed December 2020

Environment Agency (2020). Land Contamination Risk Management (LCRM). Available at: https://www.gov.uk/guidance/land-contamination-how-to-manage-the-risks. Accessed December 2020

Environmental Quality Standard (EQS): Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

LQM/ CIEH (2015). Suitable 4 Use Levels (S4ULs). Land Quality Management/ Chartered Institute of Environmental Health

MCHW – Volume 1 – Specification for Highways Works, Series 600, Earthworks, (2016)

The UK Drinking Water Standards: Water Supply (Water Quality) Regulations 2016.