M5 Junction 10 Improvements Scheme

Environmental Statement

Appendix 10.7

Ground Investigation Report

TR010063 - APP 6.15

Regulation 5 (2) (a)

Planning Act 2008

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

Volume 6

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Gloucestershire County Council

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Infrastructure Planning

Planning Act 2008

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

M5 Junction 10 Improvements Scheme

Development Consent Order 202[x]

6.15 Environmental Statement:

Appendix 10.7 Ground Investigation Report

Regulation Number:	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference	TR010063
Application Document Reference	TR010063/APP/6.15
Author:	M5 Junction 10 Improvements Scheme Project Team

Version	Date	Status of Version
Rev 0	December 2023	DCO Application

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1. Introduction

1.1. Scope

1.1.1. Atkins have been commissioned by Gloucestershire County Council (GCC) to compile a Ground Investigation Report (GIR) for the M5 Junction 10 Improvement Scheme to the west of Cheltenham.

1.1.2. This report has been prepared in accordance with BS EN 1997-2 (BSI) and the Design Manual for Roads and Bridges CD 622 Managing Geotechnical Risk (Highways England, 2020) as a part of the Geotechnical Certification.

1.2. Scheme Background

1.2.1. Gloucestershire faces significant challenges to achieve its vision for economic growth. The Joint Core Strategy (JCS) is a partnership between Gloucester City Council, Cheltenham Borough Council (CBC) and Tewkesbury Borough Council (TBC) which sets out a strategic planning framework for the three areas. The Adopted JCS 2011-2031 is a coordinated strategic development plan, adopted in December 2017, which shows how the region will develop and includes a shared spatial vision targeting 35,175 new homes and 39,500 new jobs by 2031.

1.2.2. Major development of new housing (c.9,000 homes) and employment land is proposed in the JCS in strategic and safeguarded allocations to the west and north-west of Cheltenham, these being: West Cheltenham (Golden Valley); North West Cheltenham (Elms Park); and safeguard land to the west and the north-west of Cheltenham. The West Cheltenham development, in turn, is linked to wider economic investment, including a government supported cyber business park (Cyber Central UK) adjacent to the Government Communications Headquarters (GCHQ) site in west Cheltenham.

1.2.3. To unlock the housing and job opportunities, a highway network is needed that has the capacity to accommodate the increased traffic it will generate, within a sustainable transport context.

1.2.4. A bid was submitted in March 2019 to Homes England to the Housing Infrastructure Fund (HIF), wherein an investment case was made for the following infrastructure improvements. Funding was successfully awarded by Homes England in March 2020 for:

- Element 1: Improvements to Junction 10 on the M5 and a new road linking Junction 10 to west Cheltenham.
- Element 2: A38/A4019 Junction Improvements at Coombe Hill.
- Element 3: A4019 widening, east of Junction 10.
- Element 4: An upgrade to Arle Court Park and Ride

1.2.5. This GIR covers the all-movements junction at M5 J10, the new Link Road and dualling of the A4019.

1.3. Purpose of the report

1.3.1. The purpose of this GIR is to present factual ground investigation data, summarise the ground model for the Scheme, establish engineering properties to inform design, complete a contamination assessment, undertake an engineering assessment relevant to the project and identify and manage geotechnical risk. This report should be read in conjunction with the following documents:

- Preliminary Sources Study Report (PSSR), HAGDMS Report No. 31930 (Atkins, 2020).

- Factual Ground Investigation Report for M5 J10 Improvements Scheme (Report Ref. 36568) by Geotechnical Engineering Ltd (GEL) dated October 2021 and herein referred to as the GI Factual Report (Geotechnical Engineering Ltd, 2022). This report is included in full as Appendix D of this GIR.

1.4. Geotechnical Category

1.4.1. This Scheme falls within Geotechnical Category 2 as defined by BS EN 1997-1. Geotechnical Category 2 is defined as "projects which include conventional types of geotechnical structures, earthworks and activities, with no exceptional geotechnical risks, unusual or difficult ground conditions or loading conditions. Designs for Category 2 should normally include quantitative geotechnical data and analysis to ensure that the fundamental requirements are satisfied. Routine procedures for field and laboratory testing and for design and execution may be used".

2. Existing Information

2.1. Location of the Scheme

2.1.1. This section of the report summarises key information presented in greater detail in the PSSR. Where applicable, supplementary information, not available previously, has been incorporated into this report. Full details of all existing background information available for the site may be found in the PSSR (Atkins, 2020).

2.1.2. M5 Junction 10 is located 76 km to the south of Birmingham, 8 km to the south of Tewkesbury, 6.5 km to the northwest of Cheltenham, and 12 km to the northeast of Gloucester. It is the northernmost of four junctions serving the Gloucester and Cheltenham urban areas.

2.1.3. The junction is in a strategically important location for the region, particularly as northern and western Cheltenham are the sites of a number of large retail parks and employment areas, and the location of planned future housing and nationally significant business development.

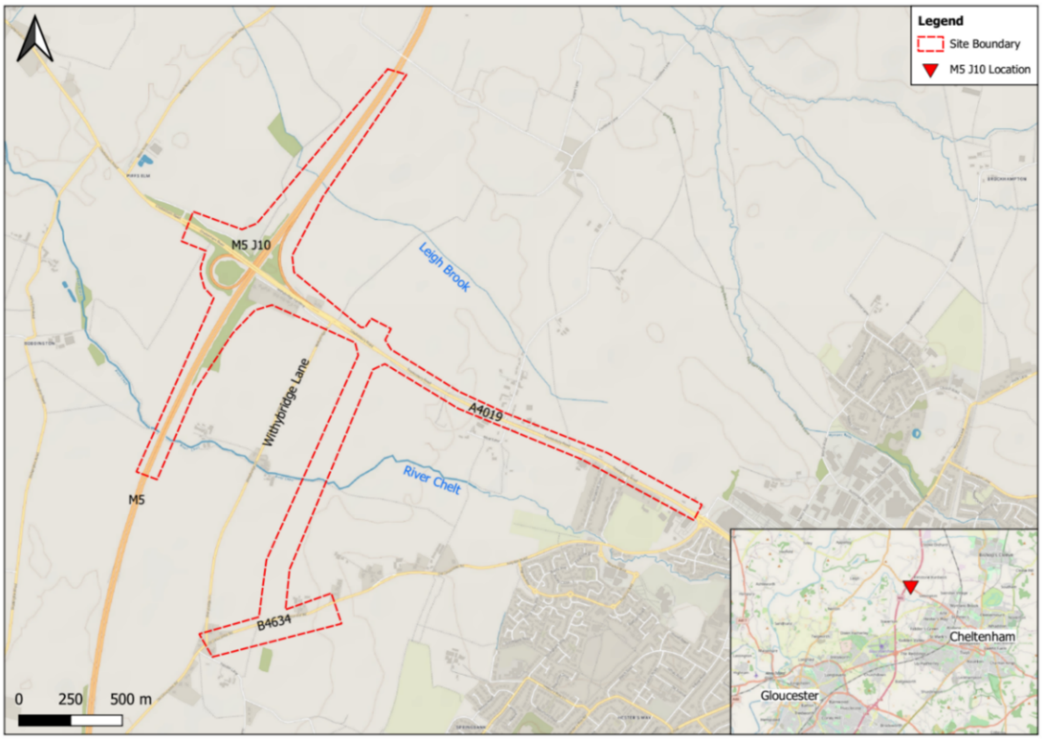

Figure 2-1 - Site Location Plan (adapted from OpenStreetMap)

2.2. Site Description

2.2.1. The Scheme is situated within low-lying predominantly agricultural land which is known to be historic River Severn flood plain. Two watercourses intersect the site: the River Chelt to the south and Leigh Brook to the north.

2.2.2. The site extents are shown in Figure 2-1, the M5 Junction 10 has the approximate Ordnance Survey (OS) grid reference 390464E, 225617N (MP79/0 – 77/0).

Description of Works

2.2.3. The works associated with each of the Scheme elements are discussed in the following sections. General Arrangement Drawings are provided application document TR010063 – APP 2.9 (as referenced in Appendix A).

M5 Junction 10 Improvements

2.2.4. The preferred route alignment for M5 J10 proposes that the junction is improved from its current 'partial movement' junction to an 'all movements' junction with the works comprising:

- The 'stopping up' of the two existing motorway slip roads (southbound exit slip and northbound entry slip).
- The provision of four new slip roads supported on embankments adjacent and parallel to the M5 alignment allowing ingress and egress to both the northbound and southbound M5 carriageways: and
- The provision of a new gyratory road supported on embankments connecting the existing A4019 road, which has an alignment perpendicular to that of the M5, to the new slip roads. The gyratory road would cross the M5 in two locations via overbridges.
- Provision of a flood storage area in the fields to the southeast of J10.

2.2.5. Further to information presented in the PSSR, Option 2 has been proposed for the new M5 J10 Interchange. This involves the demolition of the existing Piffs Elm Interchange Bridge, replacing it with two new interchange bridge structures located to the southwest and northeast of the current bridge. The A4019 road would be reinstated to its current alignment on embankments to the northwest and southeast of the junction connecting to the interchange at the central point of the gyratory road. The works would also include the demolition of the reinforced concrete retaining wall currently located between the A4019 and the properties at Withybridge Gardens, to the southeast of the motorway junction. In addition, both the existing Piffs Elm culvert and Barn Farm culvert will be extended whilst it is planned for the existing Piffs Elm Service culvert to be abandoned.

Dualling of the A4019

2.2.6. The Scheme involves the widening of the existing A4019 road into the adjacent verges to the east of M5 Junction 10 allowing the existing single lane carriageways to be dualled providing two lanes in each direction. The works also include the provision of a new junction between the dualled A4019 road and the new Link Road to the south whilst also allowing for a connection to a possible future land development to the north.

West Cheltenham Link Road

2.2.7. A new Link Road connects the A4019 to the north with the B4634 to the south. The Link Road is to be located within currently undeveloped agricultural land with the works comprising:

- Single lane northbound and southbound carriageways with a separated two-way segregated cycle track and footway, supported on embankments, aligned parallel to the existing Withybridge Lane to the west.
- Two groups of flood culverts to facilitate crossing the flood plain.
- A bridge to facilitate crossing of the River Chelt.
- The provision of either a new roundabout or signalised junction at the south end of the Link Road forming a junction with the existing B4634 (390530E, 223904N).

2.3. Topography

2.3.1. Topographic and Environment Agency LiDAR mapping indicates that the site and the surrounding area is relatively flat, varying in elevation from approximately 20-38 m Above Ordnance Datum (AOD) rising in an easterly direction. The Scheme varies from this general elevation where the A4019 road crosses the M5 motorway via embankments at an elevation of approximately 28 m AOD.

2.4. Geology

2.4.1. The geology in the vicinity of the site has been determined using information gathered from the freely available British Geological Survey (BGS) 1:50,000 Scale Geological Map – Sheet 216 (British Geological Survey, 1988), geological memoirs (British Geological Survey, 1989) and the BGS Online GeoIndex service (British Geological Survey, 2020). A detailed description of the geological conditions is provided in the following sections and shown on Figure 2-2 below.

Made Ground

2.4.2. The BGS GeoIndex (British Geological Survey, 2020) indicates a large area of artificially modified ground approximately 100 m north of the Scheme extents, this area is associated with the historic Colman's Farm landfill site located to the west of the M5 between MP 76/4 to 76/7. Additionally, an area of worked ground (void) is indicated approximately 215 m southeast of the Scheme extents adjacent to the A4019. This is indicated to be an area where the ground level has been lowered as a result of an unspecified man-made excavation. As shown in Figure 2-2, no other Made Ground deposits are indicated within the immediate vicinity of the Scheme. However, it is anticipated that Made Ground associated with the construction of the local infrastructure (roads, bridges, culverts) will be present across the site. It is known that the embankments around the existing M5 J10 were formed from locally-won reworked Charmouth Mudstone Formation.

Superficial Deposits

2.4.3. The BGS GeoIndex (British Geological Survey, 2020) indicates that the majority of the site is underlain by superficial deposits comprising Alluvium and Cheltenham Sand and Gravels which are deposited along the alignment of the existing watercourses, as shown in Figure 2-2.

2.4.4. Geological memoirs (British Geological Survey, 1989) describe the Alluvium as 'stiff grey to brownish clay' overlying 'local deposits of silt, peat and gravel' of approximately 1-2 m thickness. These memoirs describe the Cheltenham Sands and Gravels as 'rounded, medium grained, well sorted quartz sand with few oolitic limestone and ironstone pebbles' with investigations within the valley of the River Chelt encountering deposits of 6 – 15.1 m thickness.

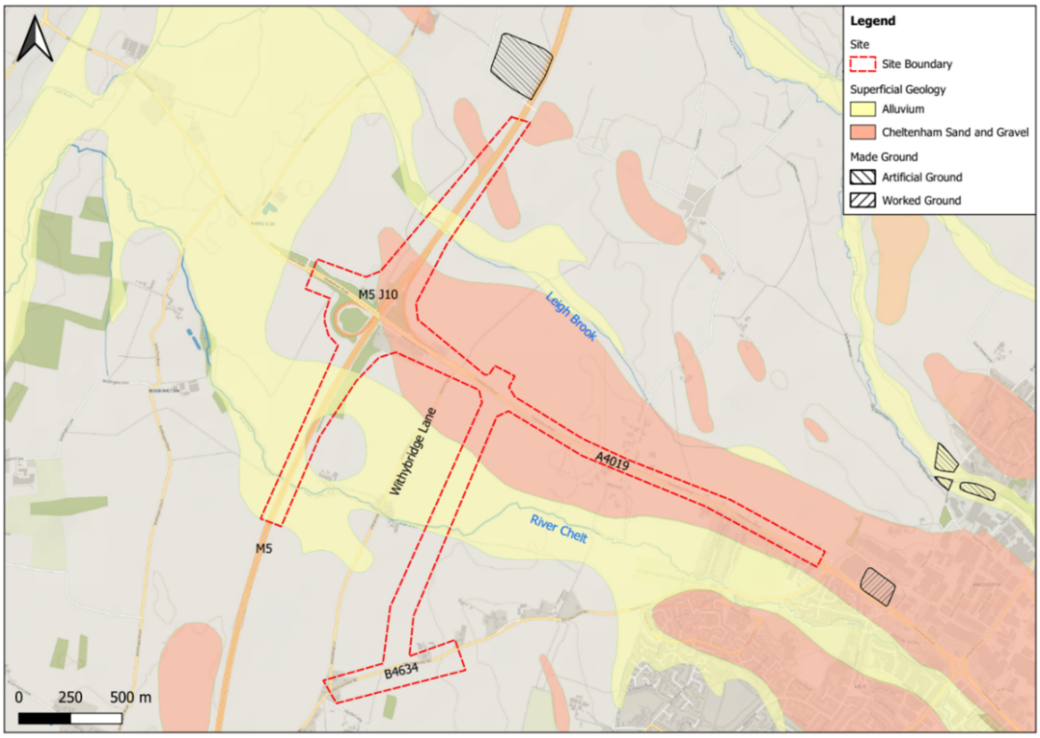

Figure 2-2 - Made Ground and Superficial Deposits (adapted from BGS and OpenStreetMap)

Bedrock Geology

2.4.5. As shown in Figure 2-3, Charmouth Mudstone Formation bedrock underlies the majority of the Scheme which is mapped to dip shallowly to the southeast at an angle of 2° (British Geological Survey, 2020; British Geological Survey, 1988). This formation is described by geological memoirs as 'grey mudstone and thin subordinate limestones' with a generalised thickness of 38m. Additionally, a small portion of the Scheme to the south of the M5 Junction 10 between MP 78/9 and 79/0 is shown to be underlain by Rugby Limestone Member which is mapped to dip shallowly to the east at a 5° angle. This formation is described by the geological memoirs as 'alternating grey, argillaceous limestones and mudstones' with a generalised thickness of 58 m (British Geological Survey, 1989). No faults are mapped within 900 m of the site boundary (shown on Figure 2-3).

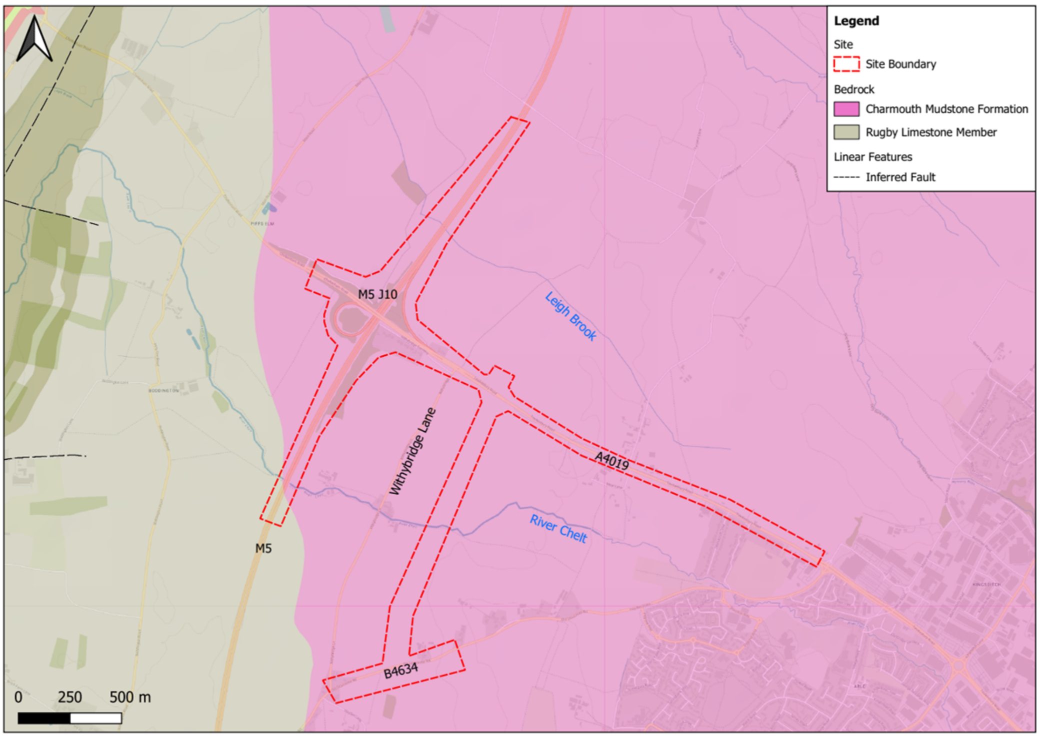

Figure 2-3 - Bedrock Geology (adapted from BGS and OpenStreetMap)

2.5. Coal Mining and Minerals

2.5.1. The Scheme is not located within a coal mining reporting area, with no coal mining related hazards mapped within 18 km (Coal Authority, 2021).

2.5.2. Review of the BGS Mineral Resources Map of Gloucestershire (British Geological Survey, 2005) indicates sub-alluvial (inferred) and sand and gravel mineral resources at the site relating to the mapped superficial deposits. Three areas licenced for mineral extraction are recorded adjacent to the A4019 approximately 0.4 to 1.0 km southwest of the site boundary, with the area mapped in closest proximity likely to be the worked ground (void) indicated by BGS mapping.

2.6. Hydrology and Hydrogeology

Coastal and River Networks

2.6.1. The Environment Agency (EA) identifies two main rivers intersecting with the Scheme extents; the River Chelt and Leigh Brook. Both rivers flow in a westerly direction joining the River Severn approximately 7.5 km west of the site boundary.

Flood Risk

2.6.2. The Scheme has been identified as being at high risk from flooding activities, with the area to the south of M5 Junction 10 surrounding the River Chelt known to be a historic River Severn flood plain with recorded flood events.

2.6.3. Environment Agency (EA) mapping indicates the Scheme to be at risk of flooding by rivers or sea with the land surrounding the River Chelt designated as a Flood Zone 2 (0.1-1% chance of flooding within any given year) and Flood Zone 3 (>1% chance of flooding within any given year) areas, as shown in Figure 2-4. This mapping also indicates localised flood defences surrounding Millhouse Farm which is situated on the alignment of the River Chelt approximately 0.9 km southeast of M5 Junction 10.

2.6.4. The Highways England Geotechnical Data Management System (HA GDMS) records five historic and one ongoing flood events at M5 Junction 10. The ongoing flood event relates to an occurrence in November 2019 where 50% of the M5 northbound hard shoulder was recorded to have flooded.

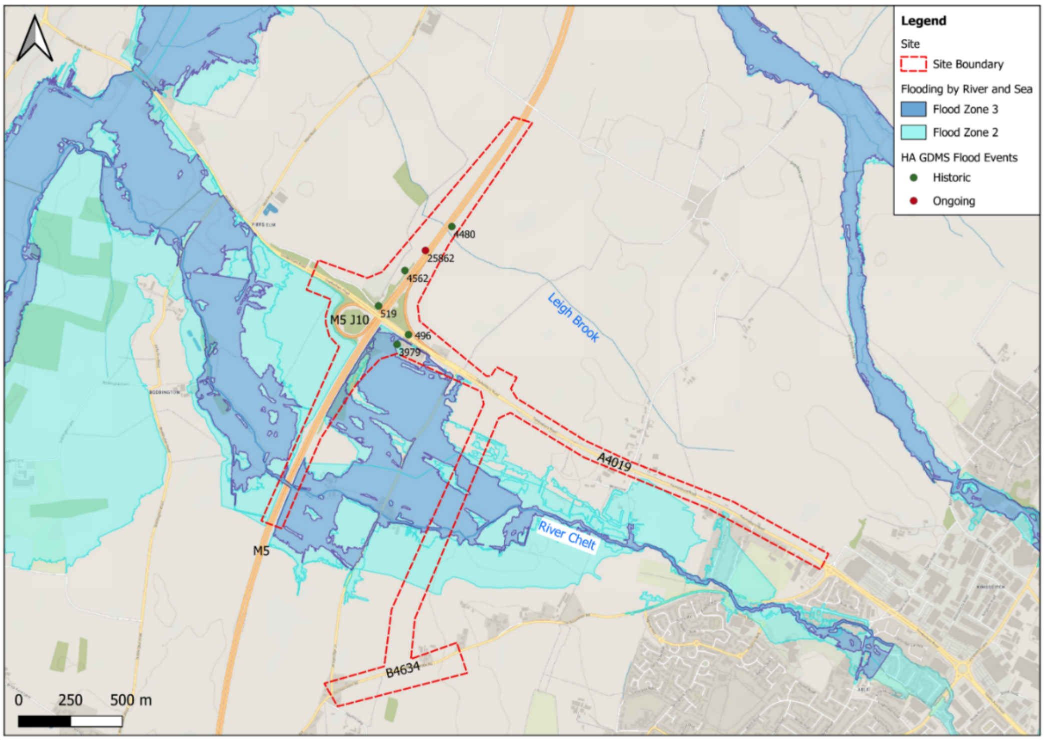

Figure 2-4 - Flood Risk Map (adapted from EA, HE and OpenStreetMaps)

2.6.5. Additionally, significant areas within the site boundary are designated as being at high risk from surface water flooding. These areas, as shown in Figure 2-5, principally include: the land immediately adjacent to the M5 southbound carriageway, along the alignments of the River Chelt and Leigh Brook and along the B4634.

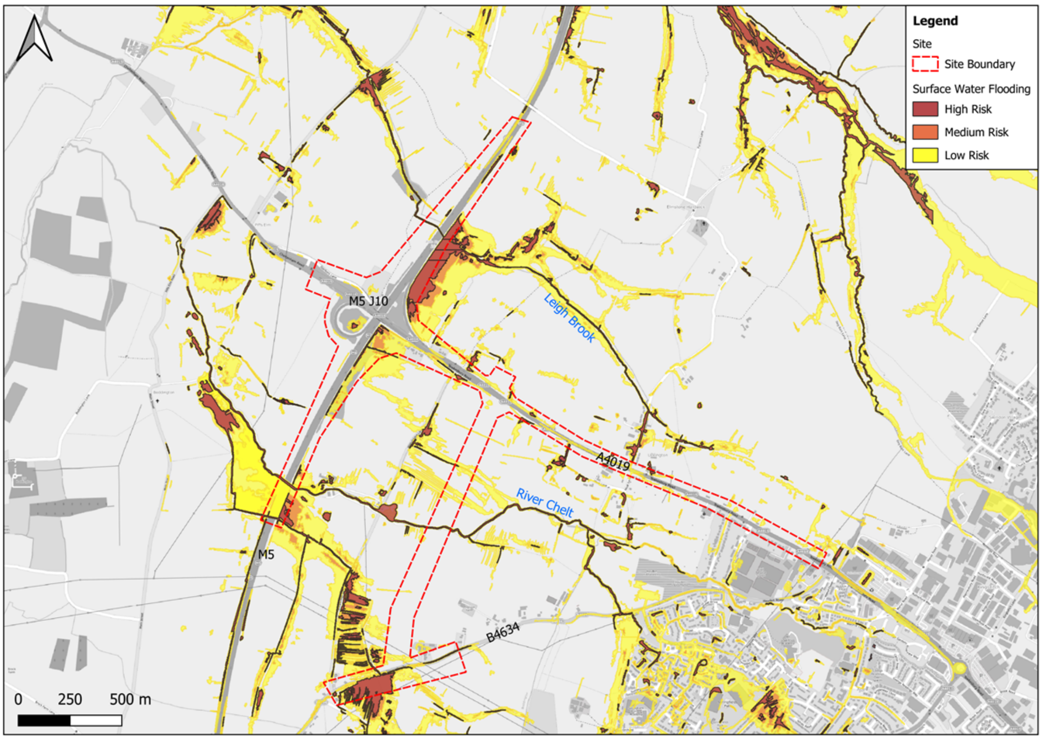

Figure 2-5 - Surface Water Flooding Risk Map (adapted from EA and OpenStreetMaps)

2.7. Hydrogeology

2.7.1. The BGS GeoIndex (British Geological Survey, 2020) indicates that the bedrock is characterised as rocks with essentially no groundwater where limestone layers form local aquifers yielding small supplies. Envirocheck mapping (Group, 2019) classifies the Charmouth Mudstone Formation as a medium vulnerability Secondary Undifferentiated Aquifer and the overlying superficial deposits as high vulnerability Secondary A Aquifers.

2.7.2. Additionally, the Scheme is not indicated to be located within a groundwater source protection zone (Department for Environment, Food and Rural Affairs (DEFRA), 2020).

2.7.3. There are no licensed groundwater abstractions on site or within 1 km of the site boundary. It should be noted that unlicensed private abstractions (<20m^3/day) could exist within the Scheme extents or in the wider area for which records are not held.

2.8. Landfill Sites

2.8.1. The PSSR (Atkins, 2020) identified three historical landfill sites within 1 km of the site boundary, situated at the following locations:

- 90m north of the site boundary adjacent to the M5 northbound carriageway (Colemans Farm landfill).
- 180m southeast of site boundary adjacent to the A4019 (Violet Villa, likely to be the worked ground (void) indicated by BGS mapping).
- 940m south of the A4019 at Arle.

2.8.2. No currently active landfill sites are located within 1km of the site boundary. There are areas of potentially infilled ground off-site within 500m of the site boundary associated with infilling of former ponds / rivers / streams located along the current A4019.

2.9. Potentially Contaminative Land Uses

2.9.1. A detailed overview of site history is provided in the PSSR report. In summary, the area has been historically used for agricultural purposes with several farms mapped throughout the local area. The A4019 and B4634 roads predate the earliest mapping, dated 1884, and, other than the construction of the M5 motorway and minor residential development, the land within and surrounding the site boundary remains broadly unchanged to the present day. Cheltenham to the southeast has seen significant expansion over time, with the majority of the remaining surrounding area retained for agricultural purposes

2.9.2. Potentially contaminative land uses located on or within 500 m of the site boundary were identified as the following:

- Potentially contaminated Made Ground of unknown provenance associated with construction of the infrastructure, which may comprise of inorganic and organic contaminants.
- Potentially contaminated Made Ground or natural soils from spills / release of fuels and organic compounds from vehicles and entrained in surface water runoff.
- Contaminants associated with historical landfill sites, 90 m north and 180m southeast.
- Atmospheric fall out of exhaust contaminants from road traffic.
- Potential contaminants from agricultural activities.
- Made Ground of unknown provenance used to infill former ponds/lakes.

3. Field and Laboratory Studies

3.1. Ground Investigations (2021)

3.1.1. Geotechnical Engineering Ltd were commissioned by GCC to undertake a ground investigation to obtain geotechnical and geo-environmental information for the site.

3.1.2. The GI Factual Report is presented in Appendix D and the ground investigation was undertaken between the 29 June to 15 October 2021. Exploratory hole location plans are included in the GI Factual Report in Appendix D. Due to the size of the site, it was segregated into the sections shown in Figure 3-1 below.

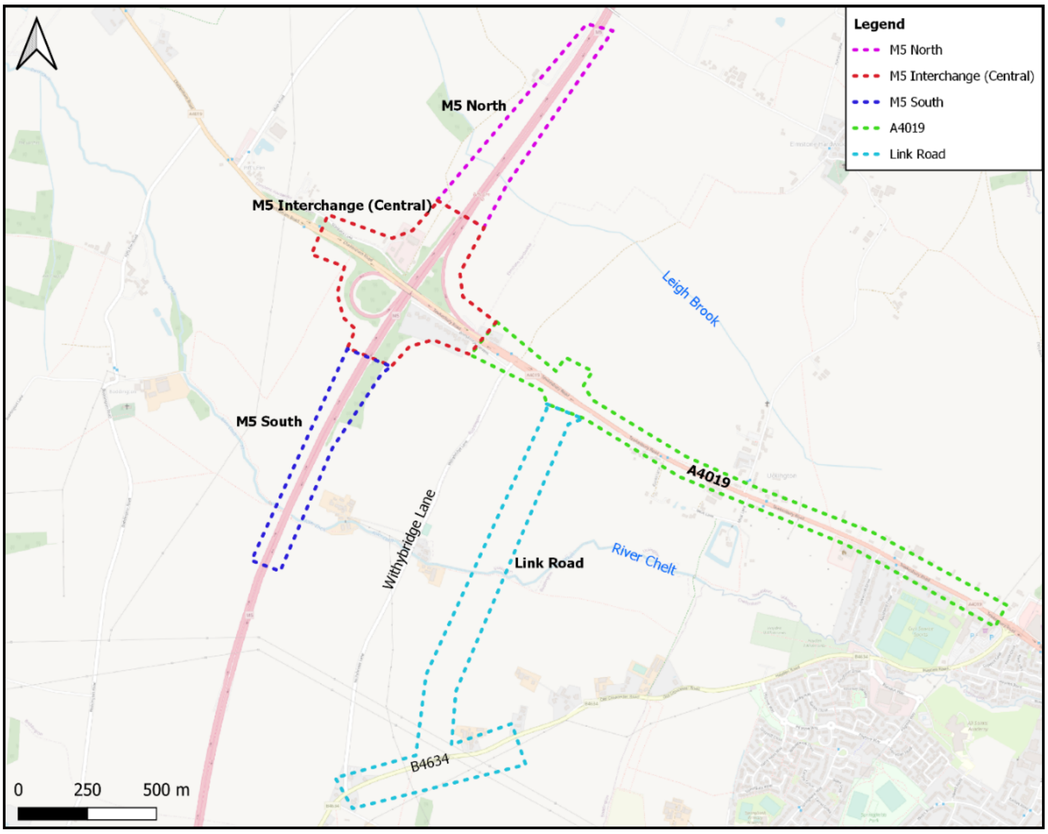

Figure 3-1 - Site Layout Sections

3.2. Aims and Reasoning behind the GI Requirements

3.2.1. The specific aims of the ground investigation were laid out in the Ground Investigation Scoping Report (GISR) - GCCM5J10-ATK-HGT-ZZ-RP-CE-000005 dated March 2021 (HAGDMS Report No. 32209) and listed below:

- Provide best practice data and information on the characteristics and thickness of underlying strata across the site to develop a ground model that can be used for detailed geotechnical design, in particular:
    - Identify depth to bedrock: determine depth, extent and classification of any superficial deposits present on site.
    - Identify and assess any areas of made ground/artificial ground present.
    - Identify and characterise any compressible or soft ground associated with river crossings.

   - Identify presence of sulphate bearing strata which could cause Thaumasite Sulphate Attack (TSA) and corrosion of buried concrete structures.
   - Characterisation of the existing junction slip road embankments for use or reuse within the development of the new gyratory.
- Assess the extent and composition of any potential existing contamination related to historical and current road building, industrial practices or farming.
- Provide best practice data and information on the groundwater conditions present across the site and obtain seasonal groundwater fluctuation data.
- Provide suitable disturbed and undisturbed soil samples for geotechnical laboratory testing.
- Provide representative soil samples and groundwater samples for geoenvironmental laboratory testing to assess potential risks to human health and controlled waters.
- Provide in situ and laboratory test results that will be used to derive the critical parameters to facilitate design parameters for the proposed road, related structures and earthworks.

3.3. Description of Fieldwork

3.3.1. The ground investigation comprised:

- 81 boreholes drilled using dynamic sampling with follow on rotary coring to a maximum depth of 20.5mbgl. Bulk, disturbed, core and environmental samples were taken at regular intervals in the boreholes for geotechnical and geo-environmental lab testing.
- 7 dynamic sampler boreholes using a terrier rig to a maximum depth of 6.4mbgl.
- 43 machine excavated trial pits were dug using a JCB 3CX excavator to a maximum depth of 4.10mbgl.
- 45 hand excavated trial pits were dug to a maximum depth of 1.3m bgl.
- 14 cone penetration tests were completed using Lankelma 20.5t truck to a maximum depth of 18.62mbgl.
- 18 insitu California Bearing Ratio (CBR) by plate loading tests.
- 19 soakaway tests in trial pits.
- 15 gas/water monitoring standpipes installed in boreholes to identify groundwater and gas levels and provide water samples for geochemical testing as summarised in Table 3-1 below:

Table 3-1 - Standpipe Installations

Borehole	Diameter (mm)	Depth (mbgl)	Response Zone (mbgl)	
			Top	Base
A4019_BH001	50	5	1.5	5
A4019_BH002	50	1.5	0.4	1.5
	50	10	6.9	10
A4019_BH010	50	4	0.95	10
LR_BH002	50	10	6.9	10

Borehole	Diameter (mm)	Depth (mbgl)	Response Zone (mbgl)	
LR_BH007	50	4	1.95	4
LR_BH012	50	6	2.4	6
LR_BH018A	50	4	1.5	4
LR_BH024	50	10	3.95	10
LR_BH026	50	10	3.95	10
M5_BH014	50	10	3.5	10.5
M5_BH027	50	10	0.5	10
M5_BH032	50	2	0.4	2
WL_WS002	50	4.8	0.8	5.25
WL_WS004	50	3.2	0.8	4.0

3.4. In-situ Tests

3.4.1. The in-situ testing undertaken during the ground investigation comprised:

- Standard penetration testing (SPT).
- Hand vane testing to determine insitu undrained shear strength values.
- Cone Penetration Testing.
- Variable head permeability tests.
- Plate load testing to determine insitu CBR values.
- Soakaway tests to determine infiltration rates as part of drainage design.

Standard Penetration Tests (SPT)

3.4.2. Standard penetration tests (SPT) were carried out in general accordance with BS EN ISO 22476 3:2005+A1:2011. A split barrel or a solid cone was used depending upon the materials encountered and the split barrel samples retained in airtight jars. SPTs were alternated with open tube sampling and were taken at 1m centres while dynamic sampling and 1.5m centres during rotary coring. The SPT results are shown on the borehole logs in Appendix D and are interpreted in Section 5 below.

Hand Vane Tests

3.4.3. Hand vane tests were carried out in suitable cohesive material. Hand vane test results are shown on the borehole logs within the factual report in Appendix D.

Cone Penetration Testing (CPT)

3.4.4. 14 cone penetration tests took place using a 20.5t Lankelma truck to a maximum depth of 18.62mbgl. Each CPT continuously measured cone end resistance, sleeve friction and pore water pressure to determine the ground strength and material type. The CPT contractors (Lankelma) report is included within Appendix D.

Variable Head Permeability Tests

3.4.5. Variable head permeability tests were carried out in general accordance with the procedures given in BS EN ISO 22282-2:2012. Falling head tests were carried out by topping up the borehole with clean water and coefficients of permeability were calculated using both the BS EN ISO 22282-2:2012 Hvorslev method and the Velocity Graph method as shown in Appendix D.

Plate Load Testing

3.4.6. 18 plate loading tests were carried out to evaluate the modulus of sub-grade reaction ‘k’ and estimate the equivalent CBR percentage. A 150mm diameter by 25mm nominal thickness plate was used for the tests and was bedded on a prepared base of kiln dried sand. Load was transmitted to the plate by jacking against the underside of a vehicle providing kentledge. The results are presented in Appendix D.

Soakaway Tests

3.4.7. 19 soakaway tests were undertaken in trial pits to determine the infiltration rate for drainage design. The trial pits were partially filled with clean water using a dedicated bowser with a 75mm diameter outlet and the fall in level recorded against time. The results are presented in Appendix D.

3.5. Geotechnical Laboratory Tests

3.5.1. The following geotechnical laboratory testing was carried out as part of the ground investigation. All results are included in the GI Factual Report in Appendix D.

Table 3-2 - Geotechnical Laboratory Testing

Test Type	Quantity
BS EN ISO 17892-1: 2014:5. Water Content	384
BS1377: Part 2: 1990:4.2-4.4&5.1-5.4, Liquid & Plastic Limits	254
BS1377: Part 2: 1990:4.5-4.6&5.1-5.4, Liquid (Casagrande Method) & Plastic Limits	3
BS EN ISO 17892-2: 2014:5.1 Density - Linear Measurement	17
BS EN ISO 17892-2: 2014:5.1 Density - Immersion	3
BS EN ISO 17892-3: 2015:5, Particle Density - Pycnometer	7
BS EN ISO 17892-4: 2016: 5.1, Particle Size Distribution - Wet Sieve	160
BS EN ISO 17892-4: 2016: 5.4, Particle Size Distribution - Pipette	158
BS1377: Part 4: 1990:3, Dry Density/Moisture Content Relationship (2.5kg)	23
BS1377: Part 4: 1990:3, Dry Density/Moisture Content Relationship (4.5kg)	2
BS1377: Part 4: 1990:5.5, MCV/Moisture Content Relationship	6
BS1377: Part 5: 1990:6.2, Dispersibility - Pinhole Method (Subcontracted)	4
BS EN ISO 17892-5: 2017, Oedometer	26
BS1377: Part 6: 1990:3.6, Consolidation in a Hydraulic Cell	1
BS1377: Part 6: 1990:6, Constant Head Permeability	3
BS1377: Part 7: 1990:4.5, Determination of Shear Strength by Direct Shear	12
BS1377: Part 7: 1990:8&9, Undrained Triaxial Compression	8
BS1377: Part 8: 1990: Effective Stress Testing	9
BS1377: Part 8: 1990: Effective Stress Testing (Subcontracted)	2

Test Type	Quantity
ISRM: Suggested Methods: 2007: Natural Moisture Content of Rock	55
ISRM: Suggested Methods: 2007: Uniaxial Compressive Strength of Rock	47
ISRM: Suggested Methods: 2007: Point Load Strength Test	308
Organic Matter Content (Subcontracted)	35
BRE SD1 Suite A (Subcontracted)	0
BRE SD1 Suite B (Subcontracted)	33
BRE SD1 Suite C (Subcontracted)	8
BRE SD1 Suite D (Subcontracted)	29
TRL 447 Suite (Subcontracted)	27
Total Sulphur (Subcontracted)	1

3.6. Geo-environmental Laboratory Testing

Soil Analysis

3.6.1. The ground investigation included appropriate soil sampling and descriptions of identified strata (in accordance with current good practice guidance) at each exploratory location. Sampling and selected analysis was informed by visual and olfactory indicators of contamination and the use of a photo-ionisation detector (PiD) to monitor for volatile organic compounds (VOCs).

3.6.2. Soil samples were recovered by Geotechnical Engineering during the intrusive investigation works with a total of 144 samples scheduled for the following analysis:

- pH.
- Organic matter.
- Inorganic parameters: cyanide (total, free and complex), sulphate, sulphide, ammoniacal nitrogen, nitrate and nitrite.
- Metals / metalloids: antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, hexavalent chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium and zinc.
- Total phenols.
- Benzene, toluene, ethylbenzene and xylene (BTEX).
- Methyl tertiary butyl ether (MTBE).
- Speciated polycyclic aromatic hydrocarbons (PAHs) USEPA16 with coronene.
- Total petroleum hydrocarbons criteria working group (TPH CWG), C5 – C44.

3.6.3. A total of 157 soil samples were also scheduled for asbestos screen (with quantification if asbestos positively identified).

3.6.4. All analysis was scheduled by Atkins and undertaken by i2 Analytical Environmental Science (i2) (a UKAS and MCERTS accredited laboratory), with original laboratory certificates are presented in the GI Factual Report (Geotechnical Engineering Ltd, 2022).

3.7. Soil-Leachate Analysis

3.7.1. A total of 114 soil samples were scheduled for the following soil-leachate analysis:

- pH.
- Inorganic parameters: cyanide (total, free and complex), sulphate, sulphide, ammoniacal nitrogen, chloride, nitrite, nitrate.
- Metals / metalloids: arsenic, boron, cadmium, chromium, hexavalent chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium and zinc.
- Total phenols.
- BTEX.
- MTBE.
- Speciated PAHs USEPA16 and coronene.
- TPH CWG, C5 – C35.

3.7.2. All analysis was scheduled by Atkins and undertaken by i2, with original laboratory certificates presented in the GI Factual Report in Appendix D.

Groundwater Analysis

3.7.3. A total of 46 groundwater samples were analysed from borehole standpipe locations and were scheduled for the water analysis summarised below:

- pH.
- Total organic carbon (TOC).
- Inorganic parameters: cyanide (total and free), sulphate, sulphide, ammoniacal nitrogen, ammonia, ammonium, chloride, nitrite, nitrate.
- Metals / metalloids: arsenic, boron, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc.
- Total phenols.
- BTEX.
- MTBE.
- Speciated PAHs USEPA16.
- TPH CWG, C5 – C35.

3.7.4. All analysis was scheduled by Atkins and undertaken by i2, with original laboratory certificates presented in the GI Factual Report in Appendix D.

Surface Water Analysis

3.7.5. Surface water samples were recovered on two occasions from upstream and downstream locations on the River Chelt (RC1 and RC2) and Leigh Brook (LB1) to identify the chemical quality of the on-site and nearest off-site potential surface water receptors to the Scheme. The upstream location of the Leigh Brook was dry on both monitoring occasions and therefore a total six samples were recovered. The surface water samples were scheduled for the following analysis:

- pH.
- Total organic carbon (TOC); Dissolved Organic Carbon (DOC).
- Calcium, Hardness.

- Inorganic parameters: cyanide (total and free), sulphate, sulphide, ammoniacal nitrogen, ammonia, ammonium, chloride, nitrite, nitrate.
- Metals / metalloids: arsenic, boron, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc.
- Total phenols.
- BTEX.
- MTBE.
- Speciated PAHs USEPA16.
- TPH CWG, C5 – C35.

3.7.6. All analysis was scheduled by Atkins and undertaken by i2, with original laboratory certificates presented in the GI Factual Report in Appendix D.

4. Ground Model

4.1. Introduction

4.1.1. The recent ground investigation has confirmed the geological succession proposed in the PSSR.

4.1.2. Made Ground and superficial deposits of Alluvium and Cheltenham Sands and Gravels are present overlying Weathered and Unweathered Charmouth Mudstone Formation (CMF).

4.1.3. Geological models for both the M5 J10 Interchange and the A4019 and Link Road are presented in Tables 4-1 and 4-2 below.

4.1.4. Geological Long Sections across the site are presented in Appendix C. Atkins has interpreted the geological strata based on our site observations, the descriptions in the exploratory hole logs, and the insitu and laboratory test data.

4.2. M5 J10 Interchange

4.2.1. Ground investigation data for the M5 J10 Interchange confirms the ground model below:

Table 4-1 - M5 J10 Interchange Ground Model

Strata	Approx. Thickness (m)	SPT 'N' Value Range
Made Ground / Embankment Fill (Reworked CMF) Firm grey gravelly silty CLAY. Gravel is angular to rounded fine to coarse limestone and sandstone.	0.5 - 12	4 – 20
Alluvium (in the vicinity of watercourses) Firm light grey mottled orange sandy gravelly CLAY. Gravel is subangular and subrounded fine and medium limestone and sandstone. Only identified in BH004A and BH005 associated with River Chelt and BH037 associated with Leigh Brook.	0.3 – 1.6	10 - 35
Cheltenham Sands and Gravels Loose to dense orangish brown clayey gravelly fine to coarse SAND. Gravel is subangular fine and medium limestone.	0.25 – 2.2	7 - 35
Weathered Charmouth Mudstone Formation Firm to stiff, occasionally soft, thinly laminated grey CLAY.	3.0 – 10	8 – 50+

Charmouth Mudstone Formation Extremely weak thinly laminated grey MUDSTONE with rare shell fragments and beds of weak to medium strong grey limestone. Fractures are sub horizontal closely and medium spaced planar smooth.	Not proven	50+

4.3. A4019 and Link Road

4.3.1. Ground investigation data for the A4019 and Link Road confirms the ground model below:

Table 4-2 - A4019 and Link Road Ground Model

Strata	Approx. Thickness (m)	SPT 'N' Value Range	Approx. Top Depth (mbgl)
Topsoil / Made Ground (where present) Vegetation over soft brown sandy silty CLAY with rootlets and fine to coarse limestone/chert gravel.	0.3 – 1.9	7 - 28	0.0
Alluvium (in the vicinity of watercourses) Orange, brown silty fine to coarse SAND with fine to medium chert gravel or soft to firm sandy SILT/CLAY.	0.5 – 2.7	3 - 14	0.5 – 2.7
Cheltenham Sands and Gravels Medium dense brown slightly clayey gravelly fine to coarse SAND. Gravel is subangular and subrounded fine and medium limestone.	0.2 – 2.4	4 - 36	0.2 – 2.4
Weathered Charmouth Mudstone Formation Firm to very stiff grey fissured, thinly laminated silty CLAY.	Up to 11m	7 – 50+	1.5 - 9.5
Charmouth Mudstone Formation Extremely weak, thinly laminated grey MUDSTONE with abundant shell fragments and beds of weak to medium strong grey limestone.	Not proven	50+	4 – 13m

4.3.2. As shown in the ground models the weathered Charmouth Mudstone Formation is generally encountered at shallow depths and produced high SPTs indicating stiff competent ground. Several machine excavated trial pits refused early in this material at depths of approximately 3mbgl.

4.3.3. The Alluvium and Cheltenham Sands and Gravels were only encountered in the vicinity of the River Chelt and Leigh Brook and tended to be a maximum of 3m in thickness.

4.4. Groundwater

4.4.1. Table 4-3 below shows the initial groundwater strikes and following depth after 20 minutes. The water strikes are most apparent within the superficial deposits just above the Weathered Charmouth Mudstone Formation.

Table 4-3 – Groundwater Strikes

Location ID	Depth of initial water strike (mbgl)	Water depth after 20 minutes (mbgl)	Distance water rose in 20 mins (m)	Stratum
A4019_BH004	1.27	1.27	0	Cheltenham Sand and Gravel
A4019_BH005	2.3	1.73	0.57	Cheltenham Sand and Gravel
A4019_BH009	1.05	0.96	0.09	Made Ground
A4019_TP006	1.6	1.51	0.09	Cheltenham Sand and Gravel
LR_BH014	1.79	1.7	0.09	Alluvium
LR_BH018A	2.5	2.5	0	Cheltenham Sand and Gravel
LR_CPTU014_IP	1.2	1.1	0.1	Alluvium
LR_TP005	1.7	1.7	0	Weathered Charmouth Formation
LR_TP013	1.8	1.6	0.2	Alluvium
LR_TP014	1.7	1.5	0.2	Alluvium
LR_TP018	2.8	1.6	1.2	Weathered Charmouth Formation
M5_BH006	0.7	0.7	0	Made Ground
M5_BH007	0.7	0.7	0	Made Ground
M5_BH008	3.01	2.92	0.09	Alluvium
M5_BH010	0.7	0.7	0	Made Ground
M5_BH026	2.41	2.35	0.06	Alluvium
M5_BH034	2	1.9	0.1	Made Ground
M5_TP001	1.9	1.75	0.15	Alluvium
M5_TP003	2.8	2.6	0.2	Weathered Charmouth Formation
M5_TP004	2.2	1.9	0.3	Cheltenham Sand and Gravel
WL_WS001	2.0	1.14	0.86	Alluvium
WL_WS003	1.2	1.05	0.15	Alluvium

WL_WS004	2.45	1.54	0.91	Alluvium
WL_WS005	2.45	1.13	1.32	Cheltenham Sand and Gravel

4.5. Visual and Olfactory Evidence of Contamination

4.5.1. Visual and olfactory indicators of potential contamination were identified during the ground investigation and are summarised below.

Table 4-4 - Areas of Potential Contamination

Location ID	Strata	Depth (m bgl)	Visual / Olfactory Observation
A4019_BH006	Made Ground	0.35 – 0.6	Moderate hydrocarbon odour
M5_BH025	Made Ground	1.20 – 2.00	Hydrocarbon odour
M5_BH027	Made Ground	0.30 – 3.00	Moderate to strong hydrocarbon odour

4.6. Aggressive Ground and Concrete Classification

4.6.1. The Charmouth Mudstone Formation can lead to Thaumasite Sulphate Attack (TSA) and has historically caused issues with degradation of the foundations of the existing Piffs Elm overbridge. As a result, it is known that foundation design will need to consider the aggressivity to concrete considering relevant design guidance (BRE Special Digest 1). A summary of BRE testing undertaken across the site is presented in Table 4-5 below. Samples were tested using the BRE Suite D test suite for brownfield sites with pyrite present. Further discussion is presented in Section 7.4.

4.6.2. Based on engineering judgement in line with BRE SD1, a Design Sulphate Class of DS-4 and ACEC class of AC-3s are recommended for design.

Table 4-5 – Summary of BRE Testing

Strata	Acid-soluble sulphate (%SO4)		pH		Total Sulphur (%)		Water soluble sulphate (mg/l SO4)	
	Min	Max	Min	Max	Min	Max	Min	Max
M5 Junction 10								
Made Ground (Reworked	0.06	0.54	7.9	8.8	0.03	1.9	10	1700
Alluvium	0.02	0.22	8.1	8.4	0.01	0.74	30	940
Charmouth Mudstone Formation	0.02	1.8	7.8	9.9	0.01	4.1	30	1800
Link Road								
Alluvium	0.01	0.08	7.5	9.1	0.03	0.1	20	470
Charmouth Mudstone Formation	0.01	1.7	7.7	9.6	0.01	3.2	80	3500

A4019								
Charmouth Mudstone Formation	0.02	0.59	8.0	8.6	0.03	1.4	400	1000

5. Ground Conditions and Material Properties

5.1. Rationale for Determining Geotechnical Characteristic Parameters

5.1.1. Geotechnical parameters for the material types expected to be encountered on the site have been determined in this section based on information and laboratory data presented in the GI Factual Report (Appendix D) and appropriate references applicable to these materials.

5.1.2. The following sections summarise the derivation of geotechnical parameters for the anticipated geology as described in Section 4.

5.1.3. Graphs for each set of geotechnical parameters (where sufficient data are available) are provided in Appendix B.

5.1.4. Values of geotechnical parameters are expressed in terms of Characteristic Values, which are defined in BSI BS EN 1997-1 (BSI, 1997) as:

5.1.5. "(1)P The selection of characteristic values for geotechnical parameters shall be based on results and derived values from laboratory and field tests, complemented by well-established experience.

5.1.6. (2)P The characteristic value of a geotechnical parameter shall be selected as a cautious estimate of the value affecting the occurrence of the limit state."

5.1.7. Note: "P" denotes that the clause is a Principal of BSI BS EN 1997-1 which means that no alternative method may be used.

5.1.8. The assessment of characteristic values in this report assumes that cautious estimates for strength and stiffness are lower estimates.

5.1.9. Geotechnical parameters for each material have been estimated as stated below:

- Geological descriptions are good indicators of the stiffness (soft/ firm/ stiff) and strength of the material
- The undrained shear strength (cu) for cohesive material has been assessed using the following:
    - Standard penetration tests (SPT)
    - Insitu hand shear vane tests
    - Unconsolidated undrained triaxial compression tests
    - Static cone penetration (CPT) tests
- The test results have been compared to the parameters provided in the BGS Lias Group report (British Geological Survey, 2012).
- The unconfined compressive strength (UCS) of the Charmouth Mudstone Formation has been assessed using the results from point load and uniaxial compressive strength tests. Correlation to establish UCS value from Point Load Test is:

$$UCS = Point\ Load\ Index * K$$

Where K is a correlation factor.

- The angle of friction is assessed from the effective strength triaxial tests and compared to the parameters provided in the BGS Lias Group report (British Geological Survey, 2012). Where effective strength triaxial test results are not available, an estimation of the constant volume angle of shearing resistance, φ'_{cv} has been made from correlation in BS 8002:2015 (BSI, 2015a) with the plasticity index given below:

$$\varphi'_{cv} = (42 - 12.5 log_{10} I_p)$$

Where I_p is plasticity index.

- The effective cohesion can be assessed from the effective strength triaxial tests and compared to the parameters provided in the BGS Lias Group report (British Geological Survey, 2012). BS 8002:2015 advises that in the absence of reliable test data the effective cohesion should be taken as zero.
- Bowles (Bowles, J.E., 2012) suggests, undrained stiffness modulus (E_u) for cohesive deposits as (200 to 500)*C_u.
- Stroud (1989) (Stroud and Butler, 1975) proposes correlations for the estimation of undrained stiffness modulus (Eu) and drained stiffness modulus (E') using the following relationships to arrive at lower-bound estimates.
  - For cohesive deposits: E_u = (1 to 1.2) *N (MPa).
  - E' = 0.9*N (MPa).
  - For granular deposits: E' = (1 to 2) *N (MPa).
  - For weak rocks: E' = (0.5 to 2) *N (MPa).
- Values of coefficient of volume compressibility (m_v) and coefficient of consolidation (c_v) are obtained from the laboratory consolidation tests.
- The Unconfined Compressive Strength (UCS) can be estimated using correlations with the SPT N values based on the method outlined in CIRIA R181 (Gannon, 1999) for weak rocks, where f1 is a factor relating to plasticity index and is typically taken as 4.5.
  - $c_u = f_1 * N$.
  - $\sigma_c = 2*c_u$.

5.2. Made Ground

5.2.1. Made Ground associated with construction of local infrastructure is generally present across the site in thicknesses up to 2.5m. However, at M5 J10, Made Ground associated with earthworks is identified up to 12m in thickness. Due to the variable composition of this material, there is a potential for this stratum to exhibit significant lateral and vertical variations. Where Made Ground has been logged along the Link Road, this is typically due to disturbance by agricultural practices.

Unit Weight and Moisture Content

5.2.2. Typical values of bulk and dry unit weight have been selected from the results of laboratory tests on undisturbed samples. Six samples were tested in the laboratory and indicated a bulk unit weight ranging from 1.9 Mg/m^3 to 2.1 Mg/m^3 with a characteristic value of 2.0 Mg/m^3.

5.2.3. Moisture content for the samples ranges from 8% to 30% (Appendix B.1.1) and the dry unit weight ranges from 1.5 Mg/m^3 to 1.7 Mg/m^3 with a characteristic value of 1.6 Mg/m^3.

Plasticity Index

5.2.4. The results of fourteen Atterberg Limit tests are presented on the A-Line chart in Appendix B.6.1. The results indicate that the Made Ground is typically classified as 'Intermediate to High Plasticity' with a lower bound value of 25% to an upper-bound value of 30% as observed from the laboratory tests.

Particle Size Distribution

5.2.5. Grading curves are presented in Appendix B.3.1 and confirm that the Made Ground is highly variable in nature.

Undrained Shear Strength

Standard Penetration Tests

5.2.6. 82 insitu SPT tests were carried out in the Made Ground during the ground investigation, giving an N value varying from 4 to 47. Based on engineering judgement, an N value of 18, corresponding to a medium dense material is suitable to be adopted. The variation in N value with depth is shown in Appendix B.4.1.

5.2.7. Using the equation mentioned in Section 5.1, in correlation with the SPT N value of 18, and considering f_1 = 4.5, c_u is typically 80 kPa.

Hand Shear Vane Tests

5.2.8. Insitu hand shear vane tests were undertaken to obtain peak and residual undrained shear strengths. Three tests were carried out at each depth and the mean was recorded on the engineer's log. Results presented in Appendix B.5.1 show undrained shear strength increasing with depth from 40 kPa to 80 kPa at 12m depth which corresponds to a 'firm to stiff' material.

Effective Stress Parameters

5.2.9. As mentioned in Section 5.1, a characteristic constant volume angle of shearing resistance ($\varphi'_{cv,k}$) is estimated in correlation with plasticity index and a lower bound value of 24° is considered appropriate. Effective cohesion is considered to be zero in accordance with BS8004:2015[20] recommendations.

Stiffness Parameters

5.2.10. Undrained and drained Young's Modulus is correlated to undrained cohesion as mentioned in Section 5.1. With an assumption of E_u=300c_u, undrained Young's Modulus (E_u) values are estimated to have a lower bound value of 8 MPa and an upper bound value of 16 MPa and drained Young's Modulus (E') estimated to be varying from 4 MPa to an upper bound value of 18 MPa.

5.3. Alluvium

5.3.1. Alluvium is present in the vicinity of watercourses (River Chelt and Leigh Brook) up to a thickness of 2.7m. This material is generally described as either a soft to firm sandy SILT/CLAY with gravel or a fine to coarse SAND with gravel.

Unit Weight and Moisture Content

5.3.2. Values of bulk and dry unit weight have been determined from the results of laboratory tests on undisturbed samples. Four samples were tested in the laboratory and indicated a bulk unit weight ranging from 1.9 Mg/m^3 to 2.0 Mg/m^3 with a characteristic value of 1.9 Mg/m^3.

5.3.3. Moisture content for the samples ranges from 9% to 30% but is typically 20% (Appendix B.1.2). The dry unit weight ranges from 1.4 Mg/m^3 to 1.6 Mg/m^3 with a characteristic value of 1.5 Mg/m^3.

Plasticity Index

5.3.4. The results of fifteen Atterberg Limit tests have been plotted on the A-Line chart in Appendix B.6.2. The results indicate that the Alluvium is of 'Intermediate to High Plasticity' with plasticity indices ranging between 23% to 40% as observed from the laboratory tests.

Particle Size Distribution

5.3.5. PSD results are plotted as grading curves in Appendix B.3.2 and indicate the presence of 53% Silt/Clay, 42% Sand and 5% Gravel.

Undrained Shear Strength

5.3.6. 10 insitu SPT tests were carried out in the Alluvium during the ground investigation, giving an N value varying from 3 to 15. Based on engineering judgement, an N value of 6, corresponding to a loose material is suitable to be adopted. The variation in N value with depth is shown in Appendix B.4.2.

5.3.7. Using the equation mentioned in Section 5.1, in correlation with the SPT N value of 6, and considering f_1 = 4.5, c_u is typically 27 kPa (Appendix B.5.1) which corresponds to a soft material.

Effective Stress Parameters

5.3.8. As mentioned in Section 5.1, effective angle of shearing resistance(φ'_{cv}) is estimated in correlation with plasticity index and a characteristic value of 23^o is considered appropriate. Effective cohesion is considered to be zero in accordance with BS8004:2015[20] recommendations.

Stiffness Parameters

5.3.9. Undrained and drained Young's Modulus is correlated to undrained cohesion as mentioned in Section 5.1. With an assumption of E_u=300c_u, undrained Young's Modulus (E_u) values are estimated to vary from 4 MPa to 20 MPa and drained Young's Modulus (E') from 2.7 MPa to 13.5 MPa.

5.3.10. A characteristic undrained Young's Modulus (E_u) = 8.1 MPa and drained Young's Modulus (E') = 5.4MPa are considered suitable.

Consolidation Parameters

5.3.11. Laboratory testing gives a value of compressibility modulus (m_v) of 0.16m^2/MN @ 50kPa applied stress. The test also indicates the coefficient of consolidation (c_v) at the same stress level to be 4.3m^2/yr. However, the Designer should consider appropriate values based on stress changes to be considered in design. Insitu consolidation behaviour can vary considerably from the laboratory and potential effects of variability should be considered.

Organic Content

5.3.12. Organic content tests were undertaken on samples of the Alluvium as follows:

- M5 J10 – five samples taken from between 0.6-4mbgl resulted in organic contents of 0.9% to 2.6%.
- Link Road – three samples taken between 0.1-1.65mbgl resulted in organic contents of 0.47% to 3%.
- Due to the organic content, the Alluvium is not suitable for use as a Class 2 General Cohesive Fill. However, it could be used as a Class 4 Landscape Fill.

5.4. Cheltenham Sands and Gravels

5.4.1. The recent ground investigation has confirmed the BGS mapping, and a pocket of sands and gravels is identified along the alignment of the A4019 and M5 J10 up to 2.4m in thickness. These deposits are typically described as "medium dense orangish brown clayey gravelly fine to coarse SAND with gravel".

Unit Weight

5.4.2. Typical values of bulk and dry unit weight have been selected from the results of laboratory tests on undisturbed samples. Laboratory testing indicates a bulk unit weight of 2.1 Mg/m^3 and a dry unit weight of 1.8 Mg/m^3.

Particle Size Distribution

5.4.3. PSD results are plotted as grading curves in Appendix B.3.3 and indicate that the material is gap graded as samples contain more than 60% sand, 28% gravel and 12% fines. Due to the high proportion of granular material, in accordance with the Specification for Highway Works (SHW), this material would be classified as a Class 1 General Granular Fill.

Standard Penetration Test

5.4.4. Thirty insitu SPT tests were carried out in the Cheltenham Sands and Gravels during the ground investigation and the variation in N value with depth is shown in Appendix B.4.3. The SPT N value is found to vary widely between 4 to 36. However, the borehole logs confirm that this material is primarily described as 'medium dense' which corresponds to an SPT N value of 10 to 30.

Stiffness Parameters

5.4.5. Drained Young's Modulus (E') is estimated to vary from 4 MPa to 36 MPa considering a lower-bound correlation with SPT N value. However, due to the scatter of results, and the fact the material is predominantly 'medium dense', a characteristic value of Young's Modulus (E') = 15 MPa is assumed.

Effective Stress Parameters

5.4.6. The effective angle of shearing resistance (φ') is estimated using Figure 3-6 in CIRIA R143 and φ' varies from 28^{o} to 38^{o} corresponding to the SPT N values. However, a characteristic effective angle of shearing resistance value of 34^{o} is assumed. For Sands and Gravels, effective cohesion is zero.

5.5. Weathered Charmouth Mudstone Formation

5.5.1. Weathered Charmouth Mudstone Formation is typically described as 'firm to very stiff grey fissured, thinly laminated silty CLAY' and is present across the site beneath the superficial deposits up to a thickness of approximately 8m.

Unit Weight and Moisture Content

5.5.2. Bulk and dry unit weight have been determined from the results of laboratory testing on 21 undisturbed samples. Tests indicated a bulk unit weight ranging from 1.8 Mg/m^3 to 2.2 Mg/m^3 with a characteristic value of 2.0 Mg/m^3.

5.5.3. Moisture content varies from 16% to 39% but is typically 21% (Appendix B.1.3). The dry unit weight is estimated to range from 1.5 Mg/m^3 to 1.9 Mg/m^3 with a characteristic value of 1.6 Mg/m^3.

Plasticity Index

5.5.4. The results from Atterberg Limit tests have been plotted on the A-Line chart in Appendix B.6.3. Results indicate that the Weathered Charmouth Mudstone Formation is of 'Intermediate to High Plasticity' with plasticity indices ranging between 17% to 37%.

Particle Size Distribution

5.5.5. PSD results are plotted as grading curves in Appendix B.3.4 and indicate that the Weathered Charmouth Mudstone Formation typically comprises 75% to 90% fines (Clay and Silt). Due to the high proportion of fines, in accordance with the Specification for Highway Works (SHW), this material would be classified as a Class 2 General Cohesive Fill.

Undrained Shear Strength

Standard Penetration Test

5.5.6. 167 insitu SPT tests were carried out in the Weathered Charmouth Mudstone Formation during the ground investigation, resulting in N values varying from 5 to refusal with increasing depth. The design line is derived as 20+3z, where z is the depth below the top of the layer. The variation in N value with depth is shown in Appendix B.4.4.

5.5.7. In correlation with the SPT N and considering f_1 = 4.5, c_u is estimated to vary from 22.5kPa to 225kPa.

Hand Vane Shear Test

5.5.8. Insitu hand shear vane tests on Weathered Charmouth Mudstone Formation, resulted in c_u results varying from 30kPa to 150kPa increasing with depth.

Triaxial Test

5.5.9. Triaxial tests indicate c_u to vary from 27kPa to 300kPa with increase in depth as shown in Appendix B.5.3.

Cone Penetration Test (CPT)

5.5.10. CPTs were carried out as a part of the ground investigation and indicate c_u to increase with depth as shown in Appendix B.5.3. The CPT test results give significantly higher values than the laboratory testing due to disturbance of samples and are considered the most realistic values.

5.5.11. In summary, the undrained shear strength increases with depth from approximately 50 kPa at the surface to 150 kPa at 8m depth. This corresponds with the description of this material as 'firm to very stiff'. The design line in Appendix B.5.3 for the Weathered Charmouth Mudstone is represented as 50+12.5z i.e. an increment of 12.5kPa per metre depth to a maximum of 8m.

Effective Stress Parameters

5.5.12. BGS Lias Group Report (British Geological Survey, 2012) states that there is a trend in decreasing effective cohesion with increased weathering of Charmouth Mudstone Formation. Effective cohesion (c') is thus recommended to be zero as observed from Table 6.11 in the BGS Lias Group Report (British Geological Survey, 2012). Effective angle of shearing resistance (ϕ') of 25^o is estimated in correlation with the plasticity index value.

Stiffness Parameters

5.5.13. Undrained and drained Young's Modulus is correlated to undrained cohesion as mentioned in Section 5.1. With a lower-bound assumption of E_u=200c_u, undrained Young's Modulus (E_u) values are estimated to vary with depth as 10+2.5z (MPa). Considering lower-bound value for correlation, drained Young's Modulus (E') is estimated to be varying as 10+1.5z, where z is the depth below the top of weathered Charmouth Mudstone Formation.

Consolidation Parameters

5.5.14. Laboratory testing conducted on 62 samples gives lower bound values of compressibility modulus (m_v) varying from 0.04 m^2/MN @400kPa to 0.10 m^2/MN @200 kPa. In addition, the average coefficient of consolidation (c_v) varies from 1.8m^2/yr @400kPa to 2.5m^2/yr @200kPa. However, the Designer should consider appropriate values based on stress changes to be considered in design. Insitu consolidation behaviour can vary considerably from laboratory, hence potential effects of variability should be considered.

5.5.15. The BGS Lias Group Report (British Geological Survey, 2012) suggests 0.16 m^2/MN @100kPa to 0.10 m^2/MN @400kPa for compressibility modulus and 1.5 m^2/yr @400kPa to 3.4m^2/yr @100kPa for coefficient of consolidation.

Compaction Parameters

5.5.16. Laboratory compaction tests indicate optimum moisture content values varying from 12.5% to 30.2% as shown in Appendix B.2.3 with corresponding maximum dry density varying from 1.44 Mg/m^3 to 1.79 Mg/m^3. However, a typical value of 21.39% for optimum moisture content and 1.56 Mg/m^3 for maximum dry density is considered appropriate based on the BGS Lias Group Report (British Geological Survey, 2012).

5.6. Charmouth Mudstone Formation

5.6.1. Charmouth Mudstone Formation bedrock underlies the entire site and is typically described as "extremely weak thinly laminated grey MUDSTONE with rare shell fragments and beds of weak to medium strong grey limestone".

Unit Weight

5.6.2. Laboratory testing indicate a bulk unit weight and dry unit weight ranging from 2.0 Mg/m^3 to 2.4 Mg/m^3 and 1.77 Mg/m^3 to 2.2 Mg/m^3 respectively. Thus, a characteristic bulk unit weight of 2.2 Mg/m^3 and dry unit weight of 1.95 Mg/m^3 are assumed.

Unconfined Compressive Strength

Standard Penetration Test

5.6.3. 256 SPT tests were carried out in the Charmouth Mudstone Formation during the ground investigation. N values increased with depth as shown in Appendix B.4.5. Using the relationship mentioned in Section 5.1, the unconfined compressive strength of the Charmouth Mudstone Formation (based on a characteristic SPT N value of 150) has been estimated as 1.35MPa.

Unconfined Compressive Strength (UCS) Test

5.6.4. UCS tests indicate UCS values varying from 0.18 MPa to 9.46 MPa with a typical value of 2MPa (Appendix B.7.1).

Point Load Test

5.6.5. Point load tests were carried out on samples of the Charmouth Mudstone Formation and the point load index $Is_{(50)}$ values have been correlated to UCS using the conversion factor K=24 (Bieniawski 1972): Both axial and diametral tests give an average UCS of approximately 3-4MPa which is higher than the UCS test results which are considered more representative.

5.6.6. Based on the above and Appendix B.7.1, a UCS value of 1MPa can be assumed at approximately 8m depth where the Weathered Charmouth Mudstone Formation grades into Unweathered Charmouth Mudstone Formation. This agrees with the material being described as 'extremely weak' and correlates with BS5930 which states that an 'extremely weak' mudstone generally has a UCS of 0.6 - 1 MPa. The UCS increases with depth to approximately 2MPa at 18m depth and this value corresponds to a 'very weak' rock according to the BGS Lias Group Report (British Geological Survey, 2012).

5.6.7. It should be noted that point load tests conducted on bands of limestone present within the Charmouth Mudstone Formation gave UCS values up to 26 MPa (Appendix B.7.1). These higher UCS values indicate the limestone bands are generally 'moderately strong' and these higher strength bands could cause issues during construction (refer to Section 7).

Stiffness Parameters

5.6.8. Drained Young's Modulus (E') has been estimated using the relationship defined by Stroud (1989) as mentioned in Section 5.1. Considering lower-bound value for correlation, drained Young's Modulus (E') is estimated to be 75 MPa for the Charmouth Mudstone Formation.

5.7. Groundwater Monitoring Results

5.7.1. Groundwater monitoring results are presented below.

Table 5-1 - Groundwater Monitoring Results

Location ID	Monitoring Date (Groundwater Level mbgl)							
	13/08/21	20/09/21	05/10/21	19/10/21	22/11/21	13/12/21	24/01/22	14/02/22
A4019_BH001	-	1.10	2.87	2.61	2.67	3.16	3.00	2.95
A4019_BH002	-	1.34* / 1.45**	0.75* / 1.10**	0.71* / 0.90**	0.22* / 1.87**	0.30* / 0.78**	0.37* / 0.70**	1.67* / 0.61**
A4019_BH010	-	1.67	1.43	3.62	1.42	1.30	1.22	1.25
LR_BH002	3.71	3.16	3.48	2.91	1.94	1.24	1.86	1.44
LR_BH007	1.29	1.30	0.11	0.91	0.92	0.96	0.89	0.82
LR_BH012	1.45	1.60	1.68	0.40	1.35	2.88	1.31	5.98
LR_BH018A	2.52	2.48	2.12	2.43	2.12	2.24	2.30	1.83
LR_BH024	1.33	1.62	1.51	0.90	1.32	1.51	1.32	1.33
LR_BH026	1.65	1.41	1.28	1.15	1.04	0.91	0.96	0.75
M5_BH014	-	1.30	1.72	1.55	1.41	1.25	1.28	1.20
M5_BH027	2.43	2.23	2.29	2.40	2.27	2.05	2.00	1.86
M5_BH032	1.70	1.60	1.31	1.00	0.80	0.45	0.70	0.35
WL_WS002	-	-	-	-	-	0.49	0.72	0.39
WL_WS004	-	-	-	-	-	0.87	0.98	0.56

Notes: * Shallow Installation / ** Deep Installation

5.8. Characteristic Geotechnical Parameters

5.8.1. Based on the information presented in Sections 5.1 to 5.7 above, the characteristic geotechnical parameters for design are summarised in Table 5-2 below.

Table 5-2 - Characteristic Geotechnical Parameters

Strata	SPT N value	Undrained Cohesion, Cu (kPa)	Effective Cohesion, c' (kPa)	Effective angle of shearing resistance, φ' (0)	Plasticity Index, PI (%)	Unit Weight, γb (Mg/m3)		Young's Modulus		Coefficient of volume compressibility mv (m2/MN)	Coefficient of consolidation Cv (m2/yr)	Unconfined compressive strength, UCS (MPa)
						Bulk	Dry	Eu (MPa)	E' (MPa)			
Made Ground	18	40+7z	0	24	25-30	2.0	1.6	8-16	4-18	-	-	-
Alluvium	6	27	0	23	23-40	1.9	1.5	8.1	5.4	0.16 @ 50kPa	4.3 @ 50kPa	-
Cheltenham Sands and Gravels	10-30	-	0	34	-	2.1	1.8	-	15	-	-	-
Weathered Charmouth Mudstone Formation	20+3z	50+12.5z	0	25	17-37	2.0	1.6	10+2.5z	10+1.5z	0.16 @100kPa 0.10 @400kPa	1.5 @400kPa 3.4 @100kPa	-
Charmouth Mudstone Formation	150	-	-	-	-	2.2	1.95	-	75	-	-	1-2

Note: z is the depth below the top of the layer.

6. Land Contamination Assessment

6.1. General

6.1.1. Land contamination is assessed through the identification of risk presented by potential contaminant linkages (PCLs), i.e. Source, Pathway, Receptor relationships.

6.1.2. The approach in the following sections is in accordance with the Environment Agency 2021 Land Contamination Risk Management (LCRM) guidance (Environment Agency, 2021).

6.1.3. The LCRM provides a technical framework for identifying and remediating contamination through the application of a risk management process. The question of whether risk is unacceptable in any particular case involves not only scientific and technical assessments, but also appropriate criteria by which to judge the risk and conclude the level of risk, which would be unacceptable, based on current guidance documents.

6.1.4. The assessment involves the development of a CSM which describes the source-pathway-receptor relationships for the site. These include:

- Potential sources of contamination from both on-site and off-site sources.
- Receptors to such contamination (humans, controlled water (groundwater/surface water), ecological systems (flora and fauna of conservation designations) and property).
- Potential pathways between sources and receptors. If all three are present, or considered likely to be present, they are described as PCLs, which can be subject to the risk assessment process.

6.1.5. The question of whether risk is unacceptable in any particular case involves scientific and technical assessments together with appropriate criteria by which to judge the risk and conclude the level of risk which would be unacceptable.

6.1.6. The approach to assessing potential risks to human health and controlled waters in the following sections is in accordance with the principles given in LCRM, i.e. application of the following assessment hierarchy:

- Tier 1 risk screening by establishment of potential pollutant linkages, i.e. the preliminary CSM (PCSM).
- Tier 2 generic quantitative assessment using Generic Assessment Criteria (GACs) that represent 'minimal' or 'tolerable' risk.
- Tier 3 quantitative risk assessment using Site Specific Assessment Criteria (SSACs) that represent 'unacceptable risk', or where generic assessment criteria are not available, or they are not applicable to the CSM.

6.1.7. The PSSR assessed historical development which may have given rise to contamination sources on and surrounding the site and identified potential receptors to that contamination.

6.1.8. Based on the recent ground investigation undertaken by Geotechnical Engineering Ltd, a Tier 1 risk screening assessment has been undertaken in Sections 6.2 to 6.6 and a Tier 2 generic quantitative risk assessment has been undertaken in Sections 6.7 to 6.11.

6.1.9. An assessment of risk has been undertaken using precautionary GAC, that represent minimal or tolerable risk, relevant to the PCLs. The potential implications of the contaminant concentrations, suitability of material for reuse and the preliminary waste classification have also been assessed.

6.1.10. It should be noted that under current health and safety legislation, construction and maintenance workers are required to carry out appropriate risk assessments and instigate appropriate mitigating measures to protect themselves, other human receptors and the environment from contamination which may be present. Such risks must be adequately mitigated by the measures required under current legislation, specifically the Construction Design and Management (CDM) Regulations (United Kingdom Parliament, 2015), which require that potential risks to human health and the environment from construction activities are appropriately identified and all necessary steps are taken to eliminate / manage that risk. On this basis, it has been assumed that personal protective equipment (PPE) and health and safety best practices will be adopted during the construction works and acute risks to construction workers / site visitors have therefore not been considered as part of this assessment.

6.2. Preliminary Conceptual Site Model

6.2.1. Based on the PSSR, the following potential sources of contamination have been identified. The list of activities and contaminants of concern listed should not be considered exhaustive and provides a guide to the likely range of contaminants which may be present at or surround the site.

On-site

6.2.2. Historical and current potentially contaminative activities which could give rise to contaminants in, on, or under the ground on site comprise:

- Made Ground comprising localised residual contamination from construction of existing carriageways and infrastructure.
- Made Ground of unknown provenance used to infill former ponds/lakes.
- Localised spills/leaks of oils on existing carriageways.
- Localised spills/leaks from farm machinery on unsurfaced farmland.
- Pesticides and fertilisers on unsurfaced farmland.
- Atmospheric fall out of exhaust contaminants from road traffic comprising inorganics and heavy metals.
- Potentially contaminated perched water/groundwater underlying the site.

Off-site

6.2.3. Contaminants from off-site sources would have to migrate to the site, generally in windblown, soil-derived dust, entrained in surface water run-off, in migrating groundwater and as migrating ground/landfill gas and vapours. Potential off-site sources of contamination which may have affected or could affect the site include the following located within 500 m of the site:

- Made Ground of unknown provenance used to infill former ponds/lakes.
- Made Ground associated with operation and infilling historical landfills.
- Surface water and road run-off from existing carriageways which may contain hydrocarbons and heavy metals.
- Pesticides and fertilisers on unsurfaced farmland.

6.3. Potential Receptors to Contamination

6.3.1. The potential receptors depend upon the current and proposed end use of the site. The site currently predominantly comprises rural land with scattered farms and rural / local roads. The future use will be a single or dual carriageway. On this basis, the following receptors have been identified as potentially affected by the planned works.

Human

6.3.2. Potential human receptors are considered to comprise:

- On-site users (pedestrians, farmers).
- On-site users (future maintenance workers).
- Future off-site users (occupants / users of future proposed adjacent residential, retail and leisure properties).

6.3.3. It has been assumed that personal protective equipment (PPE) and health & safety best practices will be adopted during the construction works and, therefore, acute risks to construction workers / site visitors have not been considered further.

Controlled Waters

6.3.4. Potential controlled waters receptors are considered to comprise:

- On-site surface watercourses (River Chelt, Leigh Brook and surface water drains).
- Off-site surface watercourses (River Chelt, Leigh Brook and surface water drains).
- Groundwater within the superficial (Alluvium and Cheltenham Sand and Gravels) Secondary A Aquifer.
- Groundwater within the bedrock (Charmouth Mudstone Formation) Secondary Undifferentiated Aquifer.

Property

6.3.5. Potential property receptors are considered to comprise:

- Existing and future below ground infrastructure (drainage).
- Off site adjacent properties (residential, commercial / leisure properties).

6.4. Potential Pathways

6.4.1. The potential pathways depend upon the current and proposed end use of the site. The site predominately comprises open fields and is proposed to be used for a road following development. On this basis, the following potential pathways have been identified.

Human Health

6.4.2. The identified human receptors could be exposed to potential contamination through the following pathways:

- Dermal contact / ingestion / inhalation of contaminants in soil and soil-derived dust.
- Dermal contact / ingestion of contaminants in groundwater within excavations.
- Off-site migration of contaminants in soil derived dust and run-off followed by dermal contact / inhalation / ingestion.

Controlled Waters

6.4.3. The identified controlled waters receptors may be affected by potential contamination by the following pathways:

- Leaching or dissolution of contaminants in soils and subsequent migration of contaminants in groundwater.
- Vertical migration of dissolved phase contaminants to the underlying groundwater.
- Lateral migration of dissolved phase contaminants in groundwater to surface water.
- Lateral migration of dissolved phase contaminants via preferential pathways such as drains.
- Migration of contaminants in surface water runoff.

Property

6.4.4. The identified property receptors may be affected by the following pathways:

- Direct contact of contaminated soils/water with infrastructure, services and structures and subsequent chemical attack.
- Direct contact of migrating contaminated groundwater within infrastructure, services and structures.
- Migration of ground gas and vapour.

6.5. Preliminary Risk Assessment

6.5.1. In order to identify PCLs to human health, controlled waters and property, a preliminary CSM was produced in the PSSR and a summary of the PCLs with a risk rating of moderate or higher is provided in Table 6-3. A preliminary qualitative assessment of the identified PCLs has been undertaken, in accordance with the CIRIA C552 report (CIRIA, 2001), with the PCLs given a risk rating based on the current condition of the planned works areas and the proposed end use.

6.5.2. The definitions of estimated risk are taken from CIRIA report C552 and the estimation of level of risk through comparison of consequence and probability are shown below in Table 6-1 and Table 6-2.

Table 6-1 - Definitions of Estimate Risk

Risk Level	Definition
Very High Risk	There is a high probability that severe harm could arise to a designated receptor or there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not already undertaken) and remediation are likely to be required.
High Risk	Harm is likely to arise to a designated receptor. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not already undertaken) is required and remedial works may be necessary in the short term and are likely over the long term.
Moderate Risk	It is possible that harm could arise to a designated receptor. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the long term.
Low Risk	It is possible that harm could arise to a designated receptor, but it is likely that this harm, if realised, would be mild. Further investigation is not

Risk Level	Definition
	necessarily required, however should be considered to confirm that there is no unanticipated contamination present.
Very Low Risk	The possibility of harm to the designated receptor is either not plausible or, if the possibility of harm is plausible, risk is considered to be very unlikely with attenuation along the exposure pathway. Further investigation is not necessarily required, however may be considered to confirm that there is no unanticipated contamination present.

Table 6-2 - Estimation of the Level of Risk by Comparison of Consequence and Probability

	Consequence[1]				
Probability[2]		Severe	Medium	Mild	Minor
	High Likelihood	Very High Risk	High Risk	Moderate Risk	Moderate / Low Risk
	Likely	High Risk	Moderate Risk	Moderate / Low Risk	Low Risk
	Low Likelihood	Moderate Risk	Moderate / Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate / Low Risk	Low Risk	Very Low Risk	Very Low Risk

[1] Consequence – The result or effect of an event occurring
[2] Probability – The likelihood or frequency of an event occurring

Table 6-3 – Preliminary Conceptual Site Model

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
On-site Site Wide Made Ground comprising localised residual contamination from construction of existing carriageways and infrastructure; Made Ground of unknown provenance used to infill former ponds/lakes; Localised spills/leaks of oils on existing carriageways; Localised spills/leaks from farm machinery on unsurfaced land; Pesticides and fertilisers associated with farming; Atmospheric fall out of exhaust contaminants from road traffic comprising inorganics and heavy metals;	On-site human health (current and future site users).	Dermal contact / ingestion / inhalation of contaminants in soil and soil-derived dust; Dermal contact / ingestion of contaminants in groundwater within excavations.	Medium	Unlikely Future maintenance on the site may require localised excavation with potential for workers to come into direct contact with soils or inhale soil derived dusts. This work is likely to be short term and infrequent. Works will be risk assessed and best practice controls are likely to be used (e.g. gloves, and protective clothing) minimising potential for exposure.	Low *although assessed as low risk, this PCL is taken forward for assessment based on relevant data obtained from the ground investigation
	On-site surface water (River Chelt, Leigh Brook and surface water drains).	Lateral migration of dissolved phase contaminants in groundwater to surface water; Lateral migration of dissolved phase contaminants via preferential pathways such as drains; Migration of contaminants in surface water runoff.	Medium	Low Likelihood The majority of the site is not located in close proximity to a surface watercourse although sections of the route cross drainage channels, the River Chelt and the Leigh Brook. The construction works are likely to result in disturbance of shallow unsaturated soils which may result in the release of contaminants in unsaturated Made Ground soils with potential migration to surface water. Where working in close proximity to watercourses, site best practice procedures require implementation of mitigation to prevent silt entering the watercourse.	Moderate/Low
	Off-site surface water (River Chelt, Leigh Brook and	Lateral migration of dissolved phase contaminants in	Medium	Low Likelihood The construction works are likely to result in disturbance of shallow unsaturated soils which	Moderate/Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
Potentially contaminated perched water/groundwater underlying the site; Localised spills/leaks of oils on existing carriageways.	surface water drains).	groundwater to surface water; Lateral migration of dissolved phase contaminants via preferential pathways such as drains; Migration of contaminants in surface water runoff.		may result in the release of contaminants in unsaturated Made Ground soils with potential migration to surface water. Best practice procedures require implementation to minimise leaching of unsaturated soils in excavations and stockpiles.	
	Groundwater in the underlying superficial and bedrock aquifers (on-site and off-site).	Leaching or dissolution of contaminants in soils and subsequent migration of contaminants in groundwater; Vertical migration of dissolved phase contaminants to the underlying groundwater	Medium	Low Likelihood The site is underlain by bedrock of the Charmouth Mudstone Formation which is a Secondary Undifferentiated Aquifer. Bedrock of the Rugby Limestone Member, a Secondary A Aquifer, underlies the site in the south-western extent. Locally, in the central area of the site, superficial Alluvium and Cheltenham Sands and Gravels are present associated with the River Chelt catchment. These strata are classified as Secondary A Aquifers. Superficial strata are absent in the northern, western and southern extents of the site. The works are likely to result in disturbance of soils during excavation and construction which may result in the release of contaminants in unsaturated Made Ground soils with potential migration to groundwater.	Moderate/Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
	On-site property (existing and future below ground infrastructure)	Direct contact of contaminated soils/water with infrastructure, services and structures and subsequent chemical attack.	Mild	Unlikely Current and future below ground infrastructure is assumed to have been / will be constructed to appropriate standards for the site to withstand attack from soil chemistry.	Very Low
	Off-site property (adjacent properties)	Direct contact of contaminated soils/water with infrastructure, services and structures and subsequent chemical attack.	Mild	Unlikely Current and future below ground infrastructure is assumed to have been / will be constructed to appropriate standards for the site to withstand attack from soil chemistry. Ground gases may be generated from areas of infilled ground. Ground gas has the potential to migrate to site in permeable strata. If natural organic strata are present on or adjacent to the site, there may be naturally occurring concentrations of ground gas. However, considering the largely rural land surrounding the site, comprising open fields, ground gases are unlikely to migrate laterally to off-site properties and would be expected to preferentially vent to atmosphere via unsurfaced ground.	Very Low
Off-site Site Wide Made Ground of unknown provenance used to infill former ponds/lakes;	On-site surface water (River Chelt and Leigh Brook).	Lateral migration of dissolved phase contaminants in groundwater to surface water; Migration of contaminants in	Medium	Low Likelihood Potentially contaminated groundwater may migrate to the site from off-site sources, potentially affecting surface water in the River Chelt and Leigh Brook.	Moderate/Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
Made Ground associated with operation and infilling historical landfills; Surface water and road run-off from existing carriageways which may contain hydrocarbons and heavy metals; and Pesticides and fertilisers associated with farming.		surface water runoff.			
	Groundwater in the underlying superficial and bedrock aquifers (on-site)	Vertical and lateral migration of dissolved phase contaminants in groundwater	Medium	Low Likelihood Potentially contaminated groundwater may migrate to the site from off-site sources. Historical or current potentially contaminative land uses have been identified including landfills 90 m north of the M5 and 180 m south-east of the A4019. Historical groundwater monitoring has shown groundwater to be at relatively shallow depths of 0.6 to 3.8 m bgl (38.9–22.1 mAOD). Therefore, groundwater is likely to be encountered during excavation works.	Moderate/Low
	On-site property (existing and future below ground infrastructure)	Direct contact of migrating contaminated groundwater within infrastructure, services and structures; Migration of ground gas / vapour.	Mild	Unlikely Current and future below ground infrastructure is assumed to have been / will be constructed to appropriate standards for the site to withstand attack from soil chemistry. Ground gases may be generated from areas of infilled ground. Ground gas has the potential to migrate to site in permeable strata. Considering the identified historical landfills in vicinity of the site closed between 48 to 53 years ago, a greater proportion of landfill gas generation would be expected to have completed and it is unlikely that landfill gas would be present to a	Very Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
				degree which would adversely affect enclosed infrastructure on the site. However, if natural organic strata are present on or adjacent to the site, there may be naturally occurring concentrations of ground gas. There are understood to not be any enclosed structures proposed as part of the Scheme and infrastructure would likely be vented and not routinely accessed.	

6.6. Generic Quantitative Risk Assessment

6.6.1. A Generic Quantitative Risk Assessment (GQRA) of potential PCLs identified as having a low/moderate risk rating or higher has been carried out using information from the recent ground investigation as summarised in this report.

6.6.2. The soil chemical data have been screened against their respective GACs to assess the risks to the previously identified receptors. The outcome of this assessment is presented in the following sections.

6.6.3. Each section of the Scheme, as defined in Figure 2-1, has been assessed separately; these sections comprise the M5 Junction, A4019 and Link Road.

6.7. Human Health Generic Quantitative Risk Assessment

6.7.1. As summarised in Section 6.1, in order to provide an assessment of the risks to humans presented by contaminants within soils, a human health GQRA has been undertaken and forms Tier 2 of the tiered approach to assessing risks from land contamination as set out in the Environment Agency LCRM.

6.7.2. The GACs used to screen the soil data include:

- Category 4 Screening Levels (C4SLs) (CL:AIRE, 2014) and in their absence.
- Atkins soil screening values (SSVs)

6.7.3. C4SLs are values that have been derived for use in England and Wales to define soils posing low or no risk to human health. The C4SLs are protective of chronic risks to human health from contaminants in soils and have been published for nine contaminants (benzo(a)pyrene, benzene, lead, arsenic, cadmium, chromium, vinyl chloride, tetrachloroethene (PCE) and trichloroethylene (TCE)) by CL:AIRE (CL:AIRE, 2014). C4SLs represent low risk levels, they are not representative of significant possibility of significant harm (SPoSH). If the C4SLs are not exceeded, land can be demonstrated as being in Category 4 as set out in the Environmental Protection Act 1990 Contaminated Land Statutory Guidance (DEFRA, 2012) and cannot be determined as contaminated land.

6.7.4. For contaminants where C4SLs are not available, Atkins has produced soil screening values (SSVs) based on minimal toxicological risk for a variety of standard land uses at 1% soil organic matter (SOM) (sand soil type) and 6% SOM (sandy loam soil type) using the CLEA v1.071 model. Input parameters are in accordance with Environment Agency and CL:AIRE SP1010 guidance (CL:AIRE, 2014).

6.7.5. For genotoxic PAHs, the benzo(a)pyrene surrogate marker approach as set out in the C4SL Project Methodology has been adopted and the ratio of PAHs fits with the toxicological study.

6.7.6. The presence of SOM is important in determining the fate and behaviour of a number of organic contaminants such as PAHs and chlorinated solvents. The mobility of these contaminants decreases with increasing SOM. Generally, the greater the SOM content the greater the sportive capacity of the soil. Atkins' derived SSVs for a 1% SOM have been used to inform the GAC as a conservative approach. The average SOM of soil samples collected from the ground investigation reported values between 1.66% and 2.18% as summarised below. Therefore, the more conservative 1% SOM SSVs have been applied for assessment.

- M5: 2.18%.
- A4019: 1.66%.
- Link Road: 2.09%.

6.7.7. Detailed guidance on human health risk assessment is provided in Science Report SR2 (Science Report SC050021/SR3, 2009), SR3 (Science Report SC050021/SR3, 2009) and the CLEA Model. The GQRA for identified human receptors has compared soil concentration data with GAC. It should be noted that the GAC may change as new policy and technical guidance, including toxicological data, are published by the Environment Agency and other authoritative sources, but they are valid at the time of writing.

6.7.8. The project comprises upgrades to the M5 J10 and the A4019 through a suburban area and the construction of a new Link Road across farmland. Therefore, to undertake the assessment, soil samples have been screened against GAC protective of an open space (residential) land use for the M5 and A4019 and an open space (parkland) land use for the Link Road. These scenarios are considerate of the exposure for current and future site users making use of the roads, pavements and adjacent residential or landscaping areas.

6.7.9. Potential acute risks resulting from short term exposure of construction workers to contamination involved with the planned development cannot be assessed using these GACs because they relate to the long-term (chronic) risk. Risks to construction workers should be managed by the contractor through their Construction Environmental Management Plans (CEMPs) and, as a minimum, should include the use of appropriate Personal Protective Equipment (PPE) and appropriate working methods.

Comparison of Soil Data with Human Health Generic Assessment Criteria

M5 Junction

6.7.10. A total of 70 samples were recovered from the M5 Junction area, collected from depths of between ground level to 5.9 m bgl. The concentration of benzo(a)pyrene (BaP) exceeded the GAC in five locations as summarised in Table 6-4.

Table 6-4 - Soil exceedances – M5 Public Open Space (Residential) 1%

Constituent	Units	GAC (mg/kg)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Benzo(a)pyrene (BaP)	mg//kg	10.3	70	0.05	38	5	M5_BH006 0.40 - 0.50 M5_BH022 0.60 - 0.70 M5_BH024 0.80 - 1.00 M5_BH025 0.30 - 0.45 M5_BH027 2.70 - 2.90

A4019

6.7.11. A total of 23 samples were recovered from the A4019 area, collected from depths of 0.05 and 0.6 m bgl. No soil samples exceeded the GAC for a public open space (residential) land use.

Link Road

6.7.12. A total of 51 samples were recovered from the Link Road area, collected from depths of 0.05 and 2.9 m bgl. No soil samples exceeded the GAC for a public open space (parkland) land use.

Asbestos

6.7.13. A total of 157 soil samples across all three areas were screened for potential asbestos fibres and asbestos containing materials (ACM) within the soil matrix. The results of the screening indicates that no asbestos was identified in any of the samples analysed.

6.8. Controlled Waters Generic Quantitative Risk Assessment

Selection of Controlled Waters Generic Assessment Criteria

6.8.1. The controlled waters GQRA has been designed to assess the potential risks posed to the identified controlled waters receptors from the migration of contaminants from identified on-site potential contamination sources. To assess potential risks to the identified receptors, a comparison of soil leachate and groundwater data against pertinent water quality standards (WQS) has been undertaken.

6.8.2. The screening criteria for controlled waters assessment are dependent on the nature of the key receptor(s).

6.8.3. The BGS GeoIndex (British Geological Survey, 2021) online geological mapping indicates that superficial deposits underlie the site, comprising Alluvium and Cheltenham Sand and Gravels which are deposited along the alignment of the existing watercourses River Chelt and Leigh Brook. The bedrock geology underlying the site comprises the Charmouth Mudstone Formation.

6.8.4. The Alluvium is classified as a Secondary A Aquifer. The Charmouth Mudstone Formation is classified as a Secondary Undifferentiated Aquifer.

6.8.5. There are no known potable water abstractions located within 1 km of the site and the site is not located within a groundwater source protection zone.

6.8.6. The River Chelt flows east to west and crosses the Link Road 680 m south of the A4019. The Leigh Brook flows east to west and crosses the M5 in the northwest of the Scheme.

6.8.7. Considering the hydrological and hydrogeological regime as summarised above, both surface water and groundwater are primary receptors for potential contamination. Soil leachate and groundwater data has therefore been screened against Water Quality Standards (WQS) comprising Environmental Quality Standards for inland freshwater (EQS) (UKHMSO, 2016), protective of aquatic life in surface water and Drinking Water Standards (DWS) protective of a potential future potable abstraction resource (UKHMSO, 2016).

6.8.8. The EQS criteria are conservative unadjusted values, which assume 100% bioavailability. To reduce conservations in the assessment, derivation of site specific criteria can be undertaken, based on the chemical characteristics of the nearest likely receiving surface watercourse.

Comparison of Soil Leachate Data with Controlled Waters Generic Assessment Criteria

Comparison of Soil Leachate Data with EQS

M5 Junction

6.8.9. A total of 57 soil leachate samples were analysed from the M5 Junction area, collected from depths of between 0.1 and 4.0 m bgl. Concentrations of ammoniacal nitrogen, nitrate, sulphate, metals and organics were identified to exceed the EQS and DWS. A summary of the exceedances is presented below in Table 6-5 and Table 6-6.

Table 6-5 - Soil Leachate EQS exceedances – M5

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Ammoniacal Nitrogen as N	mg/l	0.2	57	0.015	2.8	18	M5_BH003 0.80 0.90, M5_BH007 0.65 0.75, M5_BH008 0.80 0.90, M5_BH009 0.80 0.90, M5_BH010 1.00 1.10, M5_BH017 1.00 1.20, M5_BH018A 0.30 0.40, M5_BH021 2.00 2.20, M5_BH023 3.80 4.00, M5_BH026 1.00 1.10, M5_BH026 2.00 2.10, M5_BH034A 0.90 1.00, M5_BH034A 1.70 1.90, M5_BH035 0.80 0.90, M5_BH036 1.00 1.10, M5_BH037 0.80 0.90, M5_BH037 2.00 2.20, M5_BH042 4.00 4.20
Nitrite as NO2	mg/l	0.01	57	0.005	6.8	14	M5_BH008 0.80 0.90, M5_BH012 0.35 0.50, M5_BH014 0.70 0.80, M5_BH014 1.10 1.20, M5_BH018A 0.30 0.40, M5_BH020 0.40 0.60, M5_BH023 3.80 4.00, M5_BH033 1.00 1.20, M5_BH041 0.80 0.90, M5_TP002 0.10 0.30, M5_TP003 0.10 0.30, M5_TP004 0.00 0.20, M5_TP006 2.40 2.60, M5_TP011 0.20 0.80
Sulphate as SO4	mg/l	400	57	1.6	2,360	17	M5_BH007 0.65 0.75, M5_BH008 0.80 0.90, M5_BH010 1.00 1.10, M5_BH017 1.00 1.20, M5_BH021 2.00 2.20, M5_BH023 3.80 4.00, M5_BH026 1.00 1.10, M5_BH026 2.00 2.10, M5_BH033 1.00 1.20, M5_BH034A 0.90 1.00, M5_BH034A 1.70 1.90, M5_BH035 0.80 0.90, M5_BH036 1.00 1.10, M5_BH037 0.80 0.90, M5_BH037 2.00 2.20, M5_TP013 1.00 2.00, M5_TP018 0.50 0.50

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Copper (dissolved)	mg/l	0.001	57	0.0007	0.026	48	M5_BH003 0.80 0.90, M5_BH006 0.40 0.50, M5_BH008 0.80 0.90, M5_BH009 0.80 0.90, M5_BH012 0.35 0.50, M5_BH012 0.70 1.00, M5_BH014 0.70 0.80, M5_BH014 1.10 1.20, M5_BH015 0.30 0.40, M5_BH015A 0.50 0.60, M5_BH017 1.00 1.20, M5_BH018A 0.30 0.40, M5_BH019 0.40 0.50, M5_BH020 0.40 0.60, M5_BH020 4.50 4.60, M5_BH022 0.60 0.70, M5_BH023 0.35 0.55, M5_BH023 3.80 4.00, M5_BH024 0.80 1.00, M5_BH025 0.30 0.45, M5_BH026 1.00 1.10, M5_BH026 2.00 2.10, M5_BH029 0.10 0.20, M5_BH030 0.90 1.10, M5_BH031 0.60 0.70, M5_BH033 0.20 0.40, M5_BH033 1.00 1.20, M5_BH033 5.90 6.00, M5_BH034A 1.70 1.90, M5_BH035 0.80 0.90, M5_BH036 1.00 1.10, M5_BH036 3.90 4.10, M5_BH037 0.80 0.90, M5_BH037 2.00 2.20, M5_BH040 0.50 0.60, M5_BH041 0.80 0.90, M5_BH042 4.00 4.20, M5_TP001 0.60 0.80, M5_TP002 0.10 0.30, M5_TP003 0.10 0.30, M5_TP004 0.00 0.20, M5_TP005 0.70 0.90, M5_TP009 1.00 1.50, M5_TP010 1.00 2.00, M5_TP011 0.20 0.80, M5_TP013 1.00 2.00, M5_TP015 0.20 0.80, M5_TP018 0.50 0.50
Iron (dissolved)	mg/l	1	57	0.018	6.7	7	M5_BH012 0.70 1.00, M5_BH015 0.30 0.40, M5_BH015A 0.50 0.60, M5_TP003 0.10 0.30,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							M5_TP004 0.00 0.20, M5_TP011 0.20 0.80, M5_TP015 0.20 0.80
Lead (dissolved)	mg/l	0.0012	57	0.001	0.01	11	M5_BH012 0.35 0.50, M5_BH012 0.70 1.00, M5_BH018A 0.30 0.40, M5_BH020 4.50 4.60, M5_BH029 0.10 0.20, M5_BH033 0.20 0.40, M5_BH035 0.80 0.90, M5_TP006 2.40 2.60, M5_TP010 1.00 2.00, M5_TP011 0.20 0.80, M5_TP018 0.50 0.50
Nickel (dissolved)	mg/l	0.004	57	0.0016	0.014	16	M5_BH003 0.80 0.90, M5_BH008 0.80 0.90, M5_BH015A 0.50 0.60, M5_BH021 2.00 2.20, M5_BH023 3.80 4.00, M5_BH033 1.00 1.20, M5_BH034A 0.90 1.00, M5_BH034A 1.70 1.90, M5_BH035 0.80 0.90, M5_BH036 1.00 1.10, M5_BH037 0.80 0.90, M5_BH037 2.00 2.20, M5_TP002 0.10 0.30, M5_TP003 0.10 0.30, M5_TP004 0.00 0.20, M5_TP011 0.20 0.80
Zinc (dissolved)	mg/l	0.014	57	0.0011	0.023	7	M5_BH008 0.80 0.90, M5_BH023 3.80 4.00, M5_BH026 1.00 1.10, M5_BH031 0.60 0.70, M5_TP003 0.10 0.30, M5_TP011 0.20 0.80, M5_TP013 1.00 2.00
TPH-CWG - Aromatic >C12 - C16	mg/l	0.01	57	0.01	0.046	1	M5_BH006 0.40 0.50
TPH-CWG - Aromatic >C16 - C21	mg/l	0.01	57	0.01	0.071	2	M5_BH006 0.40 0.50, M5_BH022 0.60 0.70
TPH-CWG - Aromatic >C21 - C35	mg/l	0.01	57	0.01	0.023	1	M5_BH006 0.40 0.50
Anthracene	mg/l	0.0001	57	1.00E-05	0.0008	1	M5_BH022 0.60 0.70

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Benzo(a)pyrene	mg/l	1.70 E-07	57	1.00E-05	0.00089	1	M5_BH022 0.60 0.70
Fluoranthene	mg/l	6.30 E-06	57	1.00E-05	0.0049	2	M5_BH006 0.40 0.50, M5_BH022 0.60 0.70

Table 6-6 - Soil Leachate DWS exceedances – M5

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Ammoniacal Nitrogen as N	mg/l	0.39	57	0.015	2.8	15	M5_BH007 0.65 0.75, M5_BH008 0.80 0.90, M5_BH009 0.80 0.90, M5_BH010 1.00 1.10, M5_BH017 1.00 1.20, M5_BH021 2.00 2.20, M5_BH023 3.80 4.00, M5_BH026 1.00 1.10, M5_BH026 2.00 2.10, M5_BH034A 0.90 1.00, M5_BH034A 1.70 1.90, M5_BH036 1.00 1.10, M5_BH037 0.80 0.90, M5_BH037 2.00 2.20, M5_BH042 4.00 4.20
Nitrite as NO2	mg/l	0.5	57	0.005	6.8	1	M5_BH018A 0.30 0.40
Sulphate as SO4	mg/l	250	57	1.6	2360	22	M5_BH003 0.80 0.90, M5_BH007 0.65 0.75, M5_BH008 0.80 0.90, M5_BH009 0.80 0.90, M5_BH010 1.00 1.10, M5_BH017 1.00 1.20, M5_BH021 2.00 2.20, M5_BH023 3.80 4.00, M5_BH026 1.00 1.10, M5_BH026 2.00 2.10, M5_BH033 1.00 1.20, M5_BH034A 0.90 1.00, M5_BH034A 1.70 1.90, M5_BH035 0.80 0.90, M5_BH036 1.00 1.10, M5_BH036 3.90 4.10, M5_BH037 0.80 0.90, M5_BH037 2.00 2.20, M5_BH041 0.80 0.90, M5_BH042 4.00 4.20, M5_TP013 1.00 2.00, M5_TP018 0.50 0.50

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Arsenic (dissolved)	mg/l	0.01	57	0.001	0.011	1	M5_TP013 1.00 2.00
Iron (dissolved)	mg/l	0.2	57	0.018	6.7	30	M5_BH006 0.40 0.50, M5_BH009 0.80 0.90, M5_BH012 0.35 0.50, M5_BH012 0.70 1.00, M5_BH015 0.30 0.40, M5_BH015A 0.50 0.60, M5_BH018A 0.30 0.40, M5_BH019 0.40 0.50, M5_BH020 0.40 0.60, M5_BH020 1.00 1.20, M5_BH020 4.50 4.60, M5_BH021 2.00 2.20, M5_BH025 0.30 0.45, M5_BH026 1.00 1.10, M5_BH029 0.10 0.20, M5_BH030 0.90 1.10, M5_BH031 0.60 0.70, M5_BH033 0.20 0.40, M5_BH035 0.80 0.90, M5_BH035 2.90 3.10, M5_BH036 1.00 1.10, M5_TP002 0.10 0.30, M5_TP003 0.10 0.30, M5_TP004 0.00 0.20, M5_TP007 0.40 0.60, M5_TP009 1.00 1.50, M5_TP010 1.00 2.00, M5_TP011 0.20 0.80, M5_TP015 0.20 0.80, M5_TP018 0.50 0.50
Manganese (dissolved)	mg/l	0.05	57	0.0016	0.1	4	M5_BH003 0.80 0.90, M5_BH008 0.80 0.90, M5_BH026 1.00 1.10, M5_BH037 2.00 2.20
Selenium (dissolved)	mg/l	0.01	57	0.004	0.03	5	M5_BH010 1.00 1.10, M5_BH017 1.00 1.20, M5_BH021 2.00 2.20, M5_BH034A 0.90 1.00, M5_BH037 0.80 0.90
Benzo(a)pyrene	mg/l	1.00E-05	57	1.00E-05	0.00089	1	M5_BH022 0.60 0.70
PAH Sum of 4 - calculated	mg/l	0.0001	57	4.00E-05	0.00262	1	M5_BH022 0.60 0.70

A4019

6.8.10. A total of 19 soil leachate samples were analysed from the A4019, collected from depths of between 0.1 and 4.0 m bgl. Concentrations of ammoniacal nitrogen, nitrate, sulphate and metals were identified to exceed the EQS and DWS. A summary of the exceedances is presented below in Table 6-7 and Table 6-8.

Table 6-7 - Soil Leachate EQS exceedances – A4019

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Ammoniacal Nitrogen as N	mg/l	0.2	19	0.015	1.9	1	A4019_BH006 0.35 0.50
Nitrite as NO2	mg/l	0.01	19	0.005	0.25	5	A4019_BH005 0.10 0.30, A4019_BH006 0.35 0.50, A4019_BH010 0.10 0.30, A4019_TP003 0.35 0.50, A4019_TP006 0.05 0.20
Sulphate as SO4	mg/l	400	19	1.4	1780	1	A4019_BH001 0.10 0.30
Copper (dissolved)	mg/l	0.001	19	0.0022	0.03	19	A4019_BH001 0.10 0.30, A4019_BH002 0.10 0.30, A4019_BH005 0.10 0.30, A4019_BH006 0.35 0.50, A4019_BH007 0.50 0.70, A4019_BH007 2.10 2.20, A4019_BH008 0.60 0.70, A4019_BH008 1.80 1.90, A4019_BH009 0.90 1.10, A4019_BH010 0.10 0.30, A4019_BH010 1.70 1.90, A4019_BH011 0.70 1.00, A4019_TP002 0.05 0.25, A4019_TP003 0.35 0.50, A4019_TP005 0.10 0.30, A4019_TP006 0.05 0.20, A4019_TP007 1.00 A4019_TP011 1.00 1.20, A4019_TP012 0.05 0.25
Iron (dissolved)	mg/l	1	19	0.055	2.8	5	A4019_BH005 0.10 0.30, A4019_BH007 2.10 2.20, A4019_TP002 0.05 0.25, A4019_TP005 0.10 0.30, A4019_TP006 0.05 0.20
Lead (dissolved)	mg/l	0.0012	19	0.001	0.01	7	A4019_BH001 0.10 0.30, A4019_BH002 0.10 0.30, A4019_BH008 0.60 0.70, A4019_TP002 0.05 0.25, A4019_TP005 0.10 0.30, A4019_TP006 0.05 0.20, A4019_TP012 0.05 0.25
Nickel (dissolved)	mg/l	0.004	19	0.0024	0.0062	6	A4019_BH005 0.10 0.30, A4019_TP002 0.05 0.25, A4019_TP003 0.35 0.50, A4019_TP005 0.10 0.30,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							A4019_TP006 0.05 0.20, A4019_TP011 1.00 1.20
Zinc (dissolved)	mg/l	0.014	19	0.0024	0.021	3	A4019_BH001 0.10 0.30, A4019_TP002 0.05 0.25 A4019_TP012 0.05 0.25

Table 6-8 - Soil Leachate DWS exceedances – A4019

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Ammoniacal Nitrogen as N	mg/l	0.39	19	0.015	1.9	1	A4019_BH006 0.35 0.50
Sulphate as SO4	mg/l	250	19	1.4	1780	1	A4019_BH001 0.10 0.30
Iron (dissolved)	mg/l	0.2	19	0.055	2.8	14	A4019_BH002 0.10 0.30, A4019_BH005 0.10 0.30, A4019_BH006 0.35 0.50, A4019_BH007 0.50 0.70, A4019_BH007 2.10 2.20, A4019_BH008 0.60 0.70, A4019_BH009 0.90 1.10, A4019_BH010 0.10 0.30, A4019_BH011 0.70 1.00, A4019_TP002 0.05 0.25, A4019_TP003 0.35 0.50, A4019_TP005 0.10 0.30, A4019_TP006 0.05 0.20, A4019_TP012 0.05 0.25
Manganese (dissolved)	mg/l	0.05	19	0.0043	0.055	1	A4019_BH006 0.35 0.50

Link Road

6.8.11. A total of 38 soil leachate samples were analysed from the Link Road, collected from depths of between 0.1 and 4.0 m bgl. Concentrations of ammoniacal nitrogen, nitrite, sulphate and metals were identified to exceed the EQS and DWS. A summary of the exceedances is presented below in Table 6-9 and Table 6-10.

Table 6-9 - Soil Leachate EQS exceedances – Link Road

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Ammoniacal Nitrogen as N	mg/l	0.2	38	0.015	1.6	5	LR_BH002 0.30, LR_BH023 2.70 2.90, LR_BH024 2.70

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							2.90, LR_TP001 1.80 1.90, LR_TP003 1.50 1.70
Nitrite as NO2	mg/l	0.01	38	0.005	1.8	16	LR_BH001 0.05 0.20, LR_BH002 0.30, LR_BH005 0.35 0.80, LR_BH009 0.40 0.80, LR_BH018 2.90 3.10, LR_BH020 0.65 0.90, LR_BH023 0.10 0.30, LR_BH025 0.30 0.45, LR_BH026 0.45 0.70, LR_TP004 0.10 0.20, LR_TP008 0.10 0.20, LR_TP011 0.50 0.70, LR_TP013 0.20 0.40, LR_TP014 0.20 0.40, LR_TP015 0.05 0.25, LR_TP019 0.10 0.20
Sulphate as SO4	mg/l	400	38	0.7	1040	4	LR_BH010 2.60 2.80, LR_BH023 2.70 2.90, LR_BH024 2.70 2.90, LR_TP001 1.80 1.90
Copper (dissolved)	mg/l	0.001	38	0.0008	0.017	37	LR_BH001 0.05 0.20, LR_BH002 0.30, LR_BH004 0.00 0.20, LR_BH005 0.35 0.80, LR_BH006 0.30 0.50, LR_BH009 0.40 0.80, LR_BH010 0.60 1.00, LR_BH010 2.60 2.80, LR_BH011 0.40 0.55, LR_BH012 0.40 0.65, LR_BH018 0.45 0.80, LR_BH018 2.90 3.10, LR_BH019 0.40 0.65, LR_BH020 0.65 0.90, LR_BH023 0.10 0.30, LR_BH023 2.70 2.90, LR_BH024 0.30 0.50, LR_BH024 2.70 2.90, LR_BH025 0.30 0.45, LR_BH026 0.45 0.70, LR_TP001 1.80 1.90, LR_TP002 0.10 0.20, LR_TP003 1.50 1.70, LR_TP004 0.10 0.20, LR_TP005 0.10 0.20, LR_TP006 0.10 0.20, LR_TP007 0.10 0.20, LR_TP008 0.10 0.20, LR_TP011 0.50 0.70, LR_TP012 0.40 0.60, LR_TP013 0.20 0.40,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							LR_TP014 0.20 0.40, LR_TP015 0.05 0.25, LR_TP017 0.40 0.60, LR_TP018 0.10 0.20, LR_TP019 0.10 0.20, LR_TP020 0.10 0.20
Iron (dissolved)	mg/l	1	38	0.018	4.5	15	LR_BH023 0.10 0.30, LR_BH024 0.30 0.50, LR_BH026 0.45 0.70, LR_TP002 0.10 0.20, LR_TP004 0.10 0.20, LR_TP005 0.10 0.20, LR_TP006 0.10 0.20, LR_TP007 0.10 0.20, LR_TP008 0.10 0.20, LR_TP011 0.50 0.70, LR_TP013 0.20 0.40, LR_TP015 0.05 0.25, LR_TP018 0.10 0.20, LR_TP019 0.10 0.20 LR_TP020 0.10 0.20
Lead (dissolved)	mg/l	0.0012	38	0.001	0.0072	21	LR_BH001 0.05 0.20, LR_BH002 0.30, LR_BH003 0.20, LR_BH005 0.35 0.80, LR_BH023 0.10 0.30, LR_BH024 0.30 0.50, LR_BH024 2.70 2.90, LR_BH026 0.45 0.70, LR_TP001 1.80 1.90, LR_TP002 0.10 0.20, LR_TP003 1.50 1.70, LR_TP004 0.10 0.20, LR_TP005 0.10 0.20, LR_TP006 0.10 0.20, LR_TP008 0.10 0.20, LR_TP011 0.50 0.70, LR_TP012 0.40 0.60, LR_TP015 0.05 0.25, LR_TP018 0.10 0.20, LR_TP019 0.10 0.20, LR_TP020 0.10 0.20
Nickel (dissolved)	mg/l	0.004	38	0.0018	0.043	16	LR_BH001 0.05 0.20, LR_BH005 0.35 0.80, LR_BH010 2.60 2.80, LR_BH023 0.10 0.30, LR_BH023 2.70 2.90, LR_TP001 1.80 1.90, LR_TP003 1.50 1.70, LR_TP004 0.10 0.20, LR_TP005 0.10 0.20, LR_TP006 0.10 0.20,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							LR_TP008 0.10 0.20, LR_TP013 0.20 0.40, LR_TP014 0.20 0.40, LR_TP015 0.05 0.25, LR_TP018 0.10 0.20, LR_TP019 0.10 0.20
Zinc (dissolved)	mg/l	0.014	38	0.0017	0.019	5	LR_BH006 0.30 0.50, LR_BH010 0.60 1.00, LR_TP013 0.20 0.40, LR_TP018 0.10 0.20, LR_TP019 0.10 0.20

Table 6-10 - Soil Leachate DWS exceedances – Link Road

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Ammoniacal Nitrogen as N	mg/l	0.39	38	0.015	1.6	2	LR_BH002 0.30, LR_TP001 1.80 1.90
Nitrite as NO2	mg/l	0.5	38	0.005	1.8	1	LR_BH002 0.30
Sulphate as SO4	mg/l	250	38	0.7	1040	5	LR_BH010 2.60 2.80, LR_BH023 2.70 2.90, LR_BH024 2.70 2.90, LR_TP001 1.80 1.90 LR_TP003 1.50 1.70
Iron (dissolved)	mg/l	0.2	38	0.018	4.5	29	LR_BH001 0.05 0.20, LR_BH002 0.30, LR_BH004 0.00 0.20, LR_BH005 0.35 0.80, LR_BH006 0.30 0.50, LR_BH009 0.40 0.80, LR_BH010 0.60 1.00, LR_BH018 0.45 0.80, LR_BH019 0.40 0.65, LR_BH020 0.65 0.90, LR_BH023 0.10 0.30, LR_BH024 0.30 0.50, LR_BH025 0.30 0.45, LR_BH026 0.45 0.70, LR_TP001 1.80 1.90, LR_TP002 0.10 0.20, LR_TP004 0.10 0.20, LR_TP005 0.10 0.20, LR_TP006 0.10 0.20, LR_TP007 0.10 0.20, LR_TP008 0.10 0.20, LR_TP011 0.50 0.70, LR_TP012 0.40 0.60,

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							LR_TP013 0.20 0.40, LR_TP014 0.20 0.40, LR_TP015 0.05 0.25, LR_TP018 0.10 0.20, LR_TP019 0.10 0.20, LR_TP020 0.10 0.20
Manganese (dissolved)	mg/l	0.05	38	0.00073	0.11	2	LR_BH010 2.60 2.80, LR_TP001 1.80 1.90
Molybdenum (dissolved)	mg/l	0.07	38	0.0004	0.14	1	LR_BH010 2.60 2.80
Nickel (dissolved)	mg/l	0.02	38	0.0018	0.043	2	LR_BH010 2.60 2.80, LR_TP001 1.80 1.90
Selenium (dissolved)	mg/l	0.01	38	0.004	0.035	2	LR_TP001 1.80 1.90, LR_TP003 1.50 1.70

6.9. Comparison of Groundwater Data with EQS

M5 Junction

6.9.1. A total of 9 groundwater samples were collected and analysed from standpipes installed in the M5 Junction area. Concentrations of chloride, sulphate and metals were identified to exceed the EQS and DWS as summarised below in Table 6-10 and Table 6-11.

Table 6-11 - Groundwater EQS exceedances – M5

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Chloride	mg/l	250	9	180	350	5	M5_BH014 6.00, M5_BH014 8.00, M5_BH032 1.60, M5_BH032 1.50, M5_BH032 4.80
Sulphate as SO4	mg/l	400	9	191	1350	3	M5_BH014 1.30, M5_BH014 6.00, M5_BH014 8.00
Boron (dissolved)	mg/l	2	9	0.2	3.2	2	M5_BH014 6.00,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							M5_BH014 8.00
Copper (dissolved)	mg/l	0.001	9	0.0032	0.016	9	M5_BH014 1.30, M5_BH014 6.00, M5_BH014 8.00, M5_BH027 2.23, M5_BH027 6.00, M5_BH027 8.00, M5_BH032 1.60, M5_BH032 1.50, M5_BH032 4.80
Mercury (dissolved)	mg/l	7.00E-05	9	5.00E-05	0.00011	2	M5_BH014 1.30, M5_BH014 6.00
Nickel (dissolved)	mg/l	0.004	9	0.0023	0.0072	4	M5_BH027 2.23, M5_BH032 1.60, M5_BH032 1.50, M5_BH032 4.80
Zinc (dissolved)	mg/l	0.0123	9	0.0019	0.014	1	M5_BH014 6.00

Table 6-12 - Groundwater DWS exceedances – M5

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Chloride	mg/l	250	9	180	350	5	M5_BH014 6.00, M5_BH014 8.00, M5_BH032 1.60, M5_BH032 1.50, M5_BH032 4.80
Sulphate as SO4	mg/l	250	9	191	1350	8	M5_BH014 1.30, M5_BH014 6.00,

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							M5_BH014 8.00, M5_BH027 2.23, M5_BH027 6.00, M5_BH027 8.00, M5_BH032 1.60, M5_BH032 4.80
Arsenic (dissolved)	mg/l	0.01	9	0.00091	0.018	1	M5_BH014 1.30
Boron (dissolved)	mg/l	1	9	0.20	3.2	3	M5_BH014 1.30, M5_BH014 6.00, M5_BH014 8.00
Selenium (dissolved)	mg/l	0.01	9	0.0014	0.035	1	M5_BH014 1.30

A4019

6.9.2. A total of 12 groundwater samples were collected and analysed from standpipes installed in the A4019 area. Concentrations of chloride, sulphate, metals and organics were identified to exceed the EQS and DWS as summarised below in Table 6-13 and Table 6-14.

Table 6-13 - Groundwater EQS exceedances – A4019

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Chloride	mg/l	250	12	35	2700	3	A4019_BH002 1.34, A4019_BH002 8.00 (Round 3), A4019_BH002 8.00 (Round 4),
Sulphate as SO4	mg/l	400	12	52.4	1400	3	A4019_BH001 1.10, A4019_BH001 4.00, A4019_BH001 1.80
Boron (dissolved)	mg/l	2	12	0.20	2.1	1	A4019_BH002 1.34
Copper (dissolved)	mg/l	0.001	12	0.0034	0.022	12	A4019_BH001 1.10, A4019_BH001 4.00, A4019_BH001 1.80, A4019_BH002 1.34, A4019_BH002 1.45, A4019_BH002 8.00 (Round 3), A4019_BH002 8.00 (Round 4), A4019_BH002 1.25, A4019_BH002 1.40, A4019_BH010 1.67,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							A4019_BH010 3.00, A4019_BH010 3.20
Nickel (dissolved)	mg/l	0.004	12	0.0033	0.015	11	A4019_BH001 1.10, A4019_BH001 4.00, A4019_BH001 1.80, A4019_BH002 1.34, A4019_BH002 1.45, A4019_BH002 1.25, A4019_BH002 8.00, A4019_BH002 1.40, A4019_BH010 1.67, A4019_BH010 3.00, A4019_BH010 3.20
TPH-CWG - Aliphatic >C10 - C12	mg/l	0.01	12	0.01	0.02	1	A4019_BH002 1.45
TPH-CWG - Aliphatic >C12 - C16	mg/l	0.01	12	0.01	0.29	1	A4019_BH002 1.45
TPH-CWG - Aliphatic >C16 - C21	mg/l	0.01	12	0.01	0.31	1	A4019_BH002 1.45
TPH-CWG - Aliphatic >C21 - C35	mg/l	0.01	12	0.01	3	1	A4019_BH002 1.45

Table 6-14 - Groundwater DWS exceedances – A4019

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Chloride	mg/l	250	12	35	2700	3	A4019_BH002 1.34, A4019_BH002 8.00, A4019_BH002 8.00
Sulphate as SO4	mg/l	250	12	52.4	1400	5	A4019_BH001 1.10, A4019_BH001 4.00, A4019_BH001 1.80, A4019_BH002 1.34, A4019_BH002 1.45
Arsenic (dissolved)	mg/l	0.01	12	0.00101	0.0102	1	A4019_BH002 1.34
Boron (dissolved)	mg/l	1	12	0.2	2.1	3	A4019_BH001 1.10, A4019_BH001 1.80, A4019_BH002 1.34

Link Road

6.9.3. A total of 25 groundwater samples were collected and analysed from standpipes installed in the Link Road area. Concentrations of chloride, sulphate, nitrate and metals were identified to exceed the EQS and DWS as summarised below in Table 6-15 and Table 6-16.

Table 6-15 - Groundwater EQS exceedances – Link Road

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Chloride	mg/l	250	25	38	2500	10	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH002 5.50, LR_BH007 1.30, LR_BH007 4.00, LR_BH024 1.62 LR_BH024 6.00, LR_BH024 8.00, LR_BH024 2.00
Sulphate as SO4	mg/l	400	25	50.4	2370	8	LR_BH002 8.00, LR_BH007 1.30, LR_BH007 4.00 (Round 2), LR_BH007 4.00 (Round 3), LR_BH024 1.62 , LR_BH024 6.00 , LR_BH024 8.00 , LR_BH024 2.00
Boron (dissolved)	mg/	2	25	0.15	2.5	3	LR_BH002 8.00, LR_BH024 6.00, LR_BH024 8.00
Cadmium (dissolved)	mg/l	8.00E-05	25	2.00E-05	0.0015	4	LR_BH007 1.30, LR_BH007 4.00 (Round 2), LR_BH007 4.00 (Round 3), LR_BH007 2.00
Copper (dissolved)	mg/l	0.001	25	0.0014	0.029	25	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH002 5.50, LR_BH007 1.30, LR_BH007 4.00 (Round 2), LR_BH007 4.00 (Round 3), LR_BH007 2.00, LR_BH012 1.60, LR_BH012 4.00, LR_BH012 5.00, LR_BH012 2.00, LR_BH018 3.50, LR_BH018A 2.48, LR_BH018A 2.83, LR_BH018A 4.00 (Round 2), LR_BH018A 4.00 (Round 3), LR_BH024 1.62, LR_BH024 6.00, LR_BH024 8.00,

Constituent	Units	EQS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
							LR_BH024 2.00, LR_BH026 1.41, LR_BH026 6.00, LR_BH026 8.00, LR_BH026 1.50
Mercury (dissolved)	mg/l	7.00E-05	25	5.00E-05	0.0005	6	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 5.50, LR_BH007 4.00, LR_BH007 2.00, LR_BH024 2.00
Nickel (dissolved)	mg/l	0.004	25	0.0032	0.015	21	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH002 5.50, LR_BH007 4.00 Round 2), LR_BH007 4.00 (Round 3), LR_BH007 2.00, LR_BH012 1.60, LR_BH012 4.00, LR_BH012 2.00, LR_BH018 3.50, LR_BH018A 2.48, LR_BH018A 2.83, LR_BH024 1.62, LR_BH024 6.00, LR_BH024 8.00, LR_BH024 2.00, LR_BH026 1.41, LR_BH026 6.00, LR_BH026 8.00, LR_BH026 1.50
Zinc (dissolved)	mg/l	0.014	25	0.0005	0.063	6	LR_BH012 2.00, LR_BH024 1.62, LR_BH024 6.00, LR_BH024 2.00, LR_BH026 6.00, LR_BH026 1.50

Table 6-16 - Groundwater DWS exceedances – Link Road

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Chloride	mg/l	250	25	38	2500	10	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH002 5.50, LR_BH007 1.30, LR_BH007 4.00, LR_BH024 1.62, LR_BH024 6.00, LR_BH024 8.00, LR_BH024 2.00

Constituent	Units	DWS (mg/l)	Number of samples	Minimum concentration	Maximum concentration	Number of exceedances	Location & Depth (m bgl)
Nitrate as NO3	mg/l	50	25	0.1	117	4	LR_BH018A 2.48, LR_BH018A 4.00 (Round 2), LR_BH018A 4.00 (Round 3), LR_BH018A 2.83
Sulphate as SO4	mg/l	250	25	50.4	2370	13	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH002 5.50, LR_BH007 1.30, LR_BH007 4.00 (Round 2), LR_BH007 4.00 (Round 3, LR_BH007 2.00, LR_BH018 3.50, LR_BH024 1.62, LR_BH024 6.00, LR_BH024 8.00, LR_BH024 2.00
Arsenic (dissolved)	mg/l	0.01	25	0.00015	0.0162	8	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH007 1.30, LR_BH007 4.00, LR_BH024 6.00, LR_BH024 8.00, LR_BH024 2.00
Boron (dissolved)	mg/l	1	25	0.15	2.5	8	LR_BH002 3.16, LR_BH002 9.00, LR_BH002 8.00, LR_BH002 5.50, LR_BH024 1.62, LR_BH024 6.00, LR_BH024 8.00, LR_BH024 2.00
Selenium (dissolved)	mg/l	0.01	25	0.0006	0.014	2	LR_BH002 9.00, LR_BH024 2.00

6.10. Comparison of Surface Water Data with EQS

6.10.1. A total of six surface water samples were collected from upstream and downstream locations of the site from the River Chelt (RC1 and RC2) and upstream from the Leigh Brook (LB1). The samples were analysed for the same suite of contaminants as the groundwater samples.

6.10.2. There were no concentrations of analysed contaminants identified exceeding the EQS screening criteria.

6.11. Summary of GQRA

Human Health – Project wide

6.11.1. Five samples were identified to exceed the GAC for BaP, located at a depth of 0.3 to 2.7 m bgl within the M5 Junction area of the Scheme. Samples recovered from M5_BH006, M5_BH022 and M5_BH024 were taken from shallow depths of 0.4 to 0.8 m bgl directly underlying an existing asphalt road layer. The samples from M5_BH025 and M5_BH027 were taken from 0.3 and 2.7 m bgl in the location of an access road adjacent to the M5 carriageway. The BaP in all of these locations is likely to be indicative of polycyclic aromatic hydrocarbon (PAH) compounds in the road surface.

6.11.2. No asbestos fibres or ACM were identified in any of the 157 analysed soil samples taken from across the M5, A4019 and Link Road areas.

6.11.3. The current and proposed site condition predominantly comprises hardstanding across the areas identified to contain exceedances against the GAC. This will reduce the likelihood of direct contact and ingestion pathways to be present by encapsulating soils beneath the road surface. A mixture of roads, unsurfaced ground, landscaping and fields are present across the remainder of the site although no exceedances were identified in the areas investigated.

6.11.4. Considering the relatively isolated exceedances of BaP in 5 locations out of 70, it is considered unlikely that there is an unacceptable risk to human health from soils across the M5, A4019 and Link Road areas.

6.11.5. However, it should be noted only a small proportion of the overall development area has been investigated and vigilance should be maintained for areas of unidentified potential contamination during construction. Advice from a contaminated land specialist should be sought if material suspected to be contaminated is identified.

Controlled Waters – Project Wide

Inorganics

6.11.6. Exceedances of ammoniacal nitrogen against both the EQS and DWS was identified to be spatially widespread across the site in soil leachate. Exceedances were absent in groundwater samples although it should be noted that sampling points were spatially limited in comparison to the soil leachate dataset. It is considered that the concentrations are likely to be indicative of natural background concentrations associated with farming of the fields on, adjacent to and surrounding the site. The absence of concentrations in groundwater suggests that leachable concentrations in soil are not sufficient to adversely affected groundwater quality.

6.11.7. Sulphate also exceeded both the EQS and DWS widespread spatially across the site in soil leachate and was also detected at similar concentrations in groundwater. As summarised in Section 2.4, the Charmouth Mudstone Formation bedrock underlying the site is noted to be a strata high in sulphate. It is therefore considered that the exceedances recorded in soil leachate and groundwater are indicative of natural background concentrations.

6.11.8. Chloride exceedances of both the EQS and DWS were recorded in groundwater samples only. Chloride groundwater exceedances were located in the M5, A4019 and Link Road areas. Chloride concentrations are within the same order of magnitude as the WQS and are considered to be marginal exceedances.

6.11.9. Taking into account the points discussed above, it is considered unlikely that there is an unacceptable risk to controlled waters from exceedances of inorganic contaminants in soils and groundwater across the M5, A4019 and Link Road areas.

Metals

6.11.10. Concentrations of metals were identified to exceed the EQS (copper, iron, lead, nickel and zinc) and DWS (arsenic, iron, manganese and selenium) in soil leachate. In groundwater samples metal exceedances of the EQS (boron, copper, mercury, nickel and cadmium) and DWS (arsenic, boron and selenium) were also identified. Where the same metals exceeded in both soil leachate and groundwater, concentrations were generally at the same magnitude.

6.11.11. The copper concentrations were generally widespread in over 80% of samples with the remaining metals generally less spatially distributed at between approximately 10% and 30% of samples. Although theoretically able to leach from soils, based on the real world concentrations recorded the concentrations in groundwater are generally not adversely affected.

Organics

6.11.12. Organic contaminants, comprising PAHs, BaP and total petroleum hydrocarbons (TPH) heavy end carbon chains C12 to C35, were identified in soil leachate. These were typically marginally above the assessment criteria and spatially isolated to samples recovered from beneath or adjacent to existing roads. Only two samples contained elevated organic contaminants in the M5 Junction area and no organic contaminants were found to be elevated above the assessment criteria across the A4019 and Link Road areas. Organic contaminants were not identified in any groundwater sample recovered from across the area within and surrounding the site boundary.

6.11.13. Therefore, it is considered unlikely that there is an unacceptable risk to controlled waters from exceedances of organic contaminants in soils and groundwater across the M5, A4019 and Link Road areas.

General

6.11.14. In addition to the points raised in the previous sections, although exceedances been identified, these are not considered to present an unacceptable risk to controlled waters receptors for the following reasons:

- The EQS screening values for copper, lead and nickel are unadjusted values, which assume 100% bioavailability. In reality the bioavailability of these contaminants is likely to be less than 100% and therefore the assessment is over conservative.
- Direct comparison of soil leachate results with WQS, does not take into account the dilution and attenuation of contaminants that may occur along the pathway between the source and the nearest surface water receptors, the River Chelt (variably between on-site to 650m from the site) and the Leigh Brook (variably between on-site to 550m from the site).
- No concentrations of analysed contaminants were identified to exceed the screening criteria in surface water samples collected from the River Chelt and Leigh Brook.
- Soil-leachate analysis is relatively aggressive resulting in an over-estimation of the concentration of a contaminant which may leach from unsaturated soils under site conditions. This results in an inherently conservative assessment, which is unlikely to be representative of actual site conditions. Therefore, marginal exceedances above the screening criteria can be considered to be unlikely to be unacceptable.

Revised CSM

6.11.15. Based on the human health and controlled waters GQRAs presented above, the preliminary CSM presented in the PSSR has been revised based on the assessments completed. The revised CSM resulting from the information discussed above is provided below in Table 6-17.

Table 6-17 - Revised Conceptual Site Model

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
On-site Site Wide Made Ground comprising localised residual contamination from construction of existing carriageways and infrastructure; Made Ground of unknown provenance used to infill former ponds/lakes; Localised spills/leaks of oils on existing carriageways; Localised spills/leaks from farm machinery on unsurfaced land; Pesticides and fertilisers associated with farming; Atmospheric fall out of exhaust contaminants from road traffic comprising inorganics and heavy metals; Potentially contaminated perched water/groundwater underlying the site;	On-site users human health (current and future site users).	Dermal contact / ingestion / inhalation of contaminants in soil and soil-derived dust; Dermal contact / ingestion of contaminants in groundwater within excavations.	Medium	Unlikely Future maintenance on the site may require localised excavation with potential for workers to come into direct contact with soils or inhale soil derived dusts. This work is likely to be short term and infrequent. Works will be risk assessed and best practice controls are likely to be used (e.g. gloves, and protective clothing) minimising potential for exposure. Soil sampling has identified limited exceedances (against a public open space end use) of organic contaminants in five samples in the vicinity of the existing M5 carriageway. These are currently encapsulated beneath hardstanding and there is, therefore, not a plausible pathway to receptors. No exceedances were identified in any other analysed samples.	Low
	On-site surface water (River Chelt, Leigh Brook and surface water drains).	Lateral migration of dissolved phase contaminants in groundwater to surface water; Lateral migration of dissolved phase contaminants via preferential pathways such as drains;	Medium	Unlikely The majority of the site is not located in close proximity to a surface watercourse although sections of the route cross drainage channels, the River Chelt and the Leigh Brook. The construction works are likely to result in disturbance of shallow unsaturated soils which may result in the release of contaminants in unsaturated Made Ground soils with potential migration to surface water. Where working in close proximity to watercourses, site best practice procedures	Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
Localised spills/leaks of oils on existing carriageways.		Migration of contaminants in surface water runoff.		require implementation of mitigation to prevent silt entering the watercourse. Soil leachate and groundwater sampling identified exceedances of metals and inorganics which were generally widespread across the Scheme. It is considered these are indicative of natural background concentrations. A large proportion of the site is unsurfaced and a lower number of exceedances and lower concentrations recorded in groundwater samples indicates groundwater quality is not adversely affected from potential leaching from unsaturated soils. No concentrations of analysed contaminants were identified to exceed the screening criteria in surface water samples collected from the River Chelt and Leigh Brook.	
	Off-site Surface water (River Chelt, Leigh Brook and surface water drains).	Lateral migration of dissolved phase contaminants in groundwater to surface water; Lateral migration of dissolved phase contaminants via preferential pathways such as drains; Migration of contaminants in surface water runoff.	Medium	Unlikely The construction works are likely to result in disturbance of shallow unsaturated soils which may result in the release of contaminants in unsaturated Made Ground soils with potential migration to surface water. Best practice procedures require implementation to minimise leaching of unsaturated soils in excavations and stockpiles. Soil leachate and groundwater sampling identified exceedances of metals and inorganics which were generally widespread across the Scheme. It is considered these are indicative of natural background concentrations. A large proportion of the site is unsurfaced and a lower number of exceedances and lower	Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
				concentrations recorded in groundwater samples indicates groundwater quality is not adversely affected from potential leaching from unsaturated soils. No concentrations of analysed contaminants were identified to exceed the screening criteria in surface water samples collected from the River Chelt and Leigh Brook.	

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
	Groundwater in the underlying superficial and bedrock aquifers.	Leaching or dissolution of contaminants in soils and subsequent migration of contaminants in groundwater; Vertical migration of dissolved phase contaminants to the underlying groundwater	Medium	Unlikely The site is underlain by bedrock of the Charmouth Mudstone Formation which is a Secondary Undifferentiated Aquifer. Bedrock of the Rugby Limestone Member, a Secondary A Aquifer, underlies the site in the south-western extent Locally, in the central area of the site, superficial Alluvium and Cheltenham Sands and Gravels are present associated with the River Chelt catchment. These strata are classified as Secondary A Aquifers. Superficial strata are absent in the northern, western and Southern extents of the site. The works are likely to result in disturbance of soils during excavation and construction which may result in the release of contaminants in unsaturated Made Ground soils with potential migration to groundwater. Soil leachate and groundwater sampling identified exceedances of metals and inorganics which were generally widespread across the Scheme. It is considered these are indicative of natural background concentrations. A large proportion of the site is unsurfaced and a lower number of exceedances and lower concentrations recorded in groundwater samples indicates groundwater quality is not adversely affected from potential leaching from unsaturated soils.	Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
Off-site Site Wide Made Ground of unknown provenance used to infill former ponds/lakes; Made Ground associated with operation and infilling historical landfills; Surface water and road run-off from existing carriageways which may contain hydrocarbons and heavy metals; and Pesticides and fertilisers associated with farming.	On-site Surface water (River Chelt and Leigh Brook).	Lateral migration of dissolved phase contaminants in groundwater to surface water; Migration of contaminants in surface water runoff.	Medium	Unlikely Potentially contaminated groundwater may migrate to the site from off-site sources, potentially affecting surface water in the River Chelt and Leigh Brook. Soil leachate and groundwater sampling identified exceedances of metals and inorganics which were generally widespread across the Scheme. It is considered these are indicative of natural background concentrations. A large proportion of the site is unsurfaced and a lower number of exceedances and lower concentrations recorded in groundwater samples indicates groundwater quality is not adversely affected from potential leaching from unsaturated soils. No concentrations of analysed contaminants were identified to exceed the screening criteria in surface water samples collected from the River Chelt and Leigh Brook.	Low
	Groundwater on-site in underlying superficial and bedrock aquifers.	Vertical and lateral migration of dissolved phase contaminants in groundwater	Medium	Unlikely Potentially contaminated groundwater may migrate to the site from off-site sources. Historical or current potentially contaminative land uses have been identified including sewage farm and landfills 90 m north of the M5 and 180 m south-east of the A4019. Historical groundwater monitoring has shown groundwater to be at relatively shallow depths of 0.6 to 3.8 m bgl (38.9–22.1 mAOD). Therefore, groundwater is likely to be encountered during excavation works.	Low

Source	Receptor	Pathway	Potential Consequence	Probability	Risk
				Soil leachate and groundwater sampling identified exceedances of metals and inorganics which were generally widespread across the Scheme. It is considered these are indicative of natural background concentrations. A large proportion of the site is unsurfaced and a lower number of exceedances and lower concentrations recorded in groundwater samples indicates groundwater quality is not adversely affected from potential leaching from unsaturated soils.	

6.12. Suitability for Material Reuse

6.12.1. Material can be reused on site if there is a certainty of use, it meets geotechnical criteria and it can be demonstrated that it does not pose an unacceptable risk to human health or the environment. Based on the sampling and laboratory testing undertaken, there are not considered to be potential unacceptable risks to human health or controlled waters from contaminants detected in soil / soil leachate from the site that have been collected from Made Ground soils. Hydrocarbon odours were recorded in three locations, M5_BH025, M5_BH027 and A4019_BH006. However, these contaminants are interpreted as likely to be related to asphalt from overlying/adjacent roads.

6.12.2. It is of note that no samples have been collected from the overlying asphalt and this is unlikely to be suitable for reuse.

6.12.3. Asbestos fibres were not detected within the soil samples analysed. If any visual ACM fragments are identified during development, these should be sorted and removed if possible.

6.12.4. Concentrations of metals, inorganics and organics in soil-leachate were identified to exceed the EQS and DWS screening values. Appropriate criteria should be developed within the Materials Management Plan (MMP) to further assess the suitability for soil reuse. Visual or olfactory evidence of contamination should be tested for acceptance.

6.12.5. It should be noted that appropriate sampling of the actual material excavated will be required with concentrations compared to appropriate reuse criteria to confirm suitability for reuse or otherwise, specific to the required end use. Specific assessment should be undertaken in relation to the reuse of soils near surface waters.

6.13. Classification of Waste

6.13.1. Material that is surplus to requirements and where there is no clear strategy for reuse on-site is classified as waste and should be disposed of in accordance with the Duty of Care as specified in the Landfill Regulations (DEFRA, 2016). If the Scheme does not require all excavated material to be retained on-site it is a waste.

6.13.2. No samples have been collected from the overlying asphalt and this material would require separate classification for disposal.

6.13.3. The actual material to be removed off-site for disposal, if any, must be appropriately classified and the classification agreed with the chosen landfill operator, including WAC testing to determine appropriate disposal measures. It is the responsibility of the waste producer to classify, treat, manage and dispose of waste appropriately and to ensure the chosen landfill is licensed to accept such material. In addition, note that individual landfill sites may have their own soil and soil leachate limits for waste acceptance as stipulated in their waste permit.

6.14. Conclusions

6.14.1. Based on the investigation and assessment presented herein, the overall contamination risk associated with the site is considered to be low for human health receptors, controlled waters and very low for property receptors under the current and future end use.

6.14.2. It is recommended that vigilance is maintained during excavation. Advice should be sought from an Environmental specialist if evidence of contamination is identified.

6.14.3. In relation to the project, the following is also likely to be required:

- Adoption of appropriate health and safety measures, practices and procedures during construction to mitigate potential risks to construction workers and visitors.
- Adoption of appropriate best practice environmental management during construction, e.g. minimisation of dust generation and migration, to mitigate potential risks to controlled waters, visitors and surrounding off-site users.

- Made Ground soils, asphalt/sub-base and natural soils should be handled and stockpiled separately to avoid cross contamination and to facilitate reuse or disposal. Suitability and classification for reuse and/or disposal will vary between material type.
- Vigilance to be maintained throughout the works for potential asbestos containing material at surface or other unexpected contamination during site clearance and earthworks in areas not previously investigated.

6.15. Limitations

6.15.1. It should be noted that, as with any physical site investigation involving discrete sampling, test results will only be representative of the point sampled and further investigation and analysis may be required should ground conditions differ from those reported. If, during any excavation / construction works, visibly contaminated material is encountered in excavations, advice should be sought from an Environmental Scientist and the requirement for additional testing and assessment of the risks agreed.

7. Engineering Assessment

7.1. Introduction

7.1.1. The works associated with the Scheme, as described in Section 2 are shown on the General Arrangement Drawings (Appendix A) and comprise the following:

- M5 Junction 10 Interchange:
  - Embankment construction for slip roads
  - Provision of a new gyratory road
  - Construction of two new overbridge structures
  - Demolition of the existing Piffs Elm overbridge
  - Extension of the existing Piffs Elm culvert
  - Extension of the existing Barn Farm Culvert
  - Provision of a flood storage area in the fields to the southeast of J10
- Low level embankments for road widening along the existing A4019.
- New West Cheltenham Link Road:
  - Embankment construction
  - Construction of two groups of flood culverts to cross the flood plain
  - Construction of River Chelt Bridge
  - Construction of two new junctions to connect the new Link Road to the A4019 and B4634 respectively

7.1.2. Based on the information reviewed previously in the PSSR and during production of this report, the following engineering considerations have been identified in relation to the works.

7.1.3. This section should also be read in conjunction with the Geological Long Sections in Appendix C.

7.2. Earthworks

M5 J10 Embankments

7.2.1. Ten embankments will be constructed as part of the new M5 J10 Interchange to accommodate the four new slip roads and the two new overbridges. These embankments are shown in Figure 7-1 below. At the time of writing this report, it is assumed that all embankments will be constructed out of locally won Charmouth Mudstone Formation (Class 2 Fill) at slope angles of 1:3. However, the following options may be considered as the design progresses:

- Use of imported general fill to create steeper embankments with slope angles of 1:2 to 1:2.5.
- Reinforced slopes with geogrid to create slope angles of 1:1.
- Reinforced soil wall (green wall) to create slope angles of 65-70o.
- Reinforced soil wall (panel/block) or RC wall to create slopes up to 89o.

7.2.2. It is likely the final design will be a combination of the above solutions and further details will be provided in the Geotechnical Design Report (GDR) for the Scheme.

7.2.3. The embankments will be founded on either reworked or weathered Charmouth Mudstone Formation which has been identified as firm to stiff, occasionally soft, from the recent GI.

This stratum is considered competent as a founding layer and detailed settlement analyses will be undertaken during the design stage and presented in the GDR to confirm this assumption.

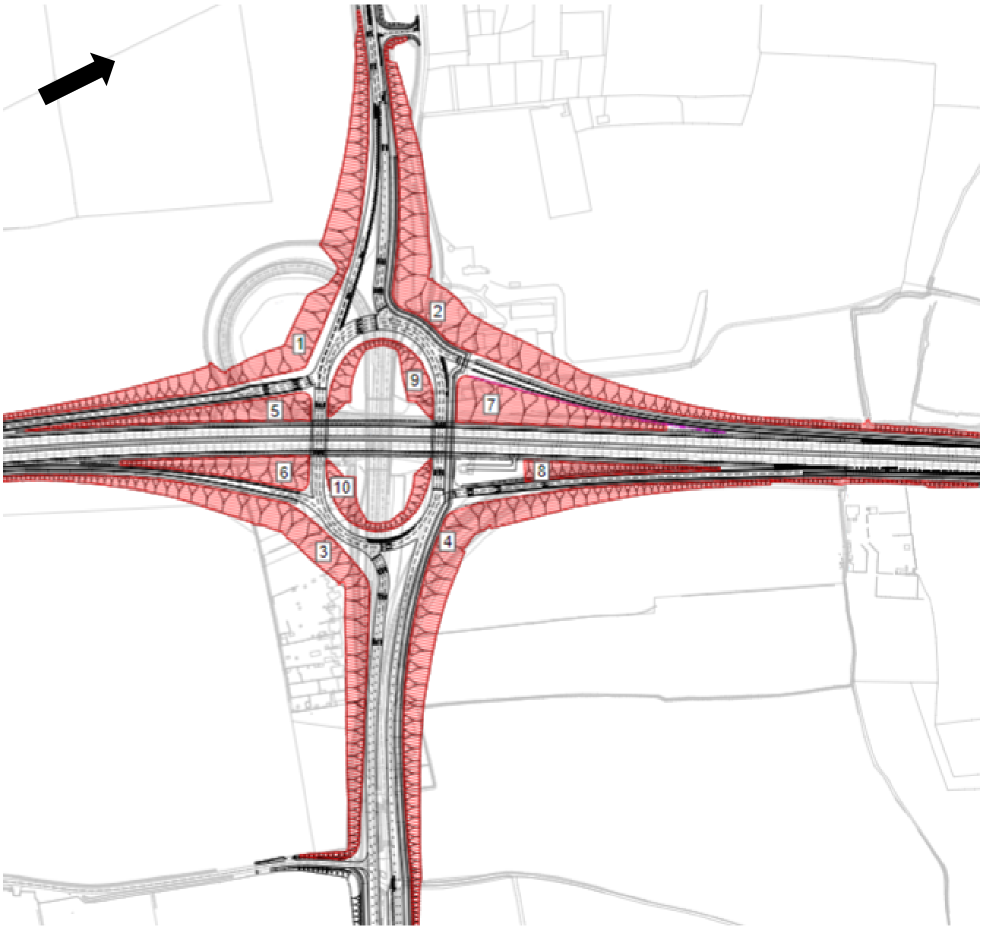

Figure 7-1 - M5 J10 Embankments

Link Road Embankments

7.2.4. The new Link Road will connect the A4019 to the north with the B4634 to the south and is located within currently undeveloped agricultural land. It will comprise single lane northbound and southbound carriageways with a separated two-way segregated cycle track and footway and will be supported on embankments, aligned parallel to the existing Withybridge Lane to the west.

7.2.5. The layout for the new Link Road is shown in the General Arrangement Drawings (Appendix A).

7.2.6. The Link Road will generally be raised on low-level embankments with side slopes of 1:3. The highest embankments will be at the location of the River Chelt bridge crossing. At this location, maximum heights of 4.5m are planned for the northern embankment and 4.6m for the southern embankment.

7.2.7. For the majority of the Link Road, the embankments will be founded on either Made Ground or Cheltenham Sands and Gravels. The Made Ground has been logged as such typically due to ground disturbance by agricultural practices. These strata are considered competent as founding layers.

7.2.8. At the location of the River Chelt bridge crossing, Alluvium up to 2m thick will be encountered. As the Alluvium is predominantly encountered as a firm sandy clay or a fine to coarse sand, any settlements are likely to occur over a short period of time and it is likely that this material can remain insitu. However, detailed settlement analyses will be undertaken during the design stage and presented in the GDR to confirm if ground improvement measures will be required or if these deposits should be removed as part of the design. If settlements are considered unacceptable, it may be preferred to build the Link Road embankments to surcharge the underlying ground which would need to be programmed into the construction works.

7.2.9. As discussed further in Section 7.8, it is currently planned that any weathered Charmouth Mudstone Formation excavated from the flood storage area can be reused as a Class 2 fill material to create the Link Road embankments.

7.3. Foundations

M5 J10 Interchange Bridges

7.3.1. The existing Piffs Elm Interchange Bridge (Structure Key 1659) will be demolished and replaced with two new overbridges.

- The new Piffs Elm Interchange Bridge (North) is 38.6m long and 24m wide.
- The new Piffs Elm Interchange Bridge (South) is 38.6m long and 18m wide.
- The existing Piffs Elm Service Culvert (Structure Key 13574) which is located on the south side of the existing Piffs Elm Interchange Bridge will be abandoned as part of the works.

7.3.2. At the time of writing this GIR, outline information on each structure and anticipated foundation types have been proposed. Confirmation of the foundation types selected will be covered in detail in the GDR for this Scheme.

Piffs Elm Interchange Bridge North

7.3.3. This integral bridge is proposed as a steel concrete composite superstructure with sleeved columns. At the time of writing this report, the foundations are estimated to comprise 10 No. piles of diameter 1.2m socketed into bedrock with wingwalls on strip footings. Further details will be presented in the Structures Option Report (SOR).

7.3.4. A Transmission Station is present adjacent to the southbound carriageway to the north of the proposed new North Bridge (shown on the GA Drawings (Appendix A)). In order so the Transmission Station can remain in place, the wing wall at this location extends along the slip road in order to retain new earthworks around it.

7.3.5. A geological cross section through the bridge is given in Appendix C. The section shows that weathered Charmouth Mudstone Formation is approximately 3.5m below ground level with bedrock encountered at approximately 7-8mbgl. Both these units have reasonable strength and stiffness and will provide reasonable vertical and lateral pile strength and stiffness, subject to detailed design. Although shallow footings may be viable if founded on the weathered Charmouth Mudstone Formation, due to the spans required and the fact the existing Piffs Elm Interchange Bridge pad foundations were replaced with piled foundations due to Thaumasite attack, a piled solution is recommended. Further information will be presented in the GDR.

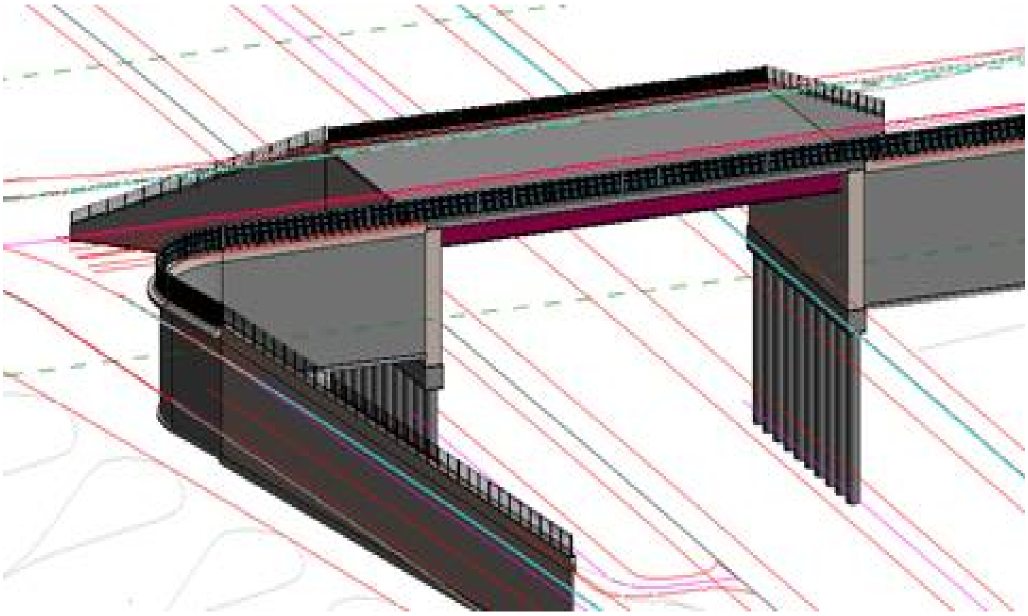

Figure 7-2 - Schematic of Proposed M5 J10 North Bridge

Piffs Elm Interchange Bridge South

7.3.6. This integral bridge is proposed as a steel concrete composite superstructure with sleeved columns. At the time of writing this report, the foundations are estimated to comprise 7 No. piles of diameter 1.2m socketed into bedrock with wingwalls on strip footings. Further details will be presented in the Structures Option Report (SOR).

7.3.7. A geological cross section through the bridge is given in Appendix C. The section shows that weathered Charmouth Mudstone Formation is approximately 3-4m below ground level with bedrock encountered at approximately 7-8mbgl. Both these units have reasonable strength and stiffness and will provide reasonable vertical and lateral pile strength and stiffness, subject to detailed design. Although shallow footings may be viable if founded on the weathered Charmouth Mudstone Formation, due to the spans required and the fact the existing Piffs Elm Interchange Bridge pad foundations were replaced with piled foundations due to Thaumasite attack, a piled solution is recommended. Further information will be presented in the GDR.

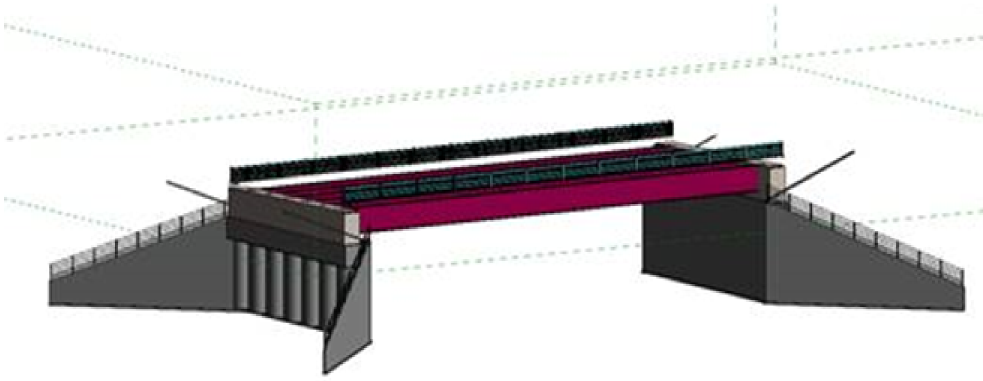

Figure 7-3 - Schematic of Proposed M5 J10 South Bridge

Extension of Piffs Elm Culvert

7.3.8. The existing Piffs Elm culvert beneath M5 J10 (Structure Key 34468) will be extended.

7.3.9. The existing culvert comprises a 1.2m diameter corrugated steel pipe and it is currently planned to extend this pipe using precast concrete. Extension lengths are 54m to the west and 47.9m to the east.

7.3.10. The culvert extensions will be founded on weathered Charmouth Mudstone Formation which is described as firm to very stiff in nature. The culvert extensions will be located under the new slip roads and due to the existing ground being flat at these locations only a shallow (600mm) trench will be excavated to lay the bedding material. As earthworks are laid for the slip roads, the culvert extensions will be incorporated into the main works, so excavation stability is not anticipated to be a concern. However, the loading of the culvert extensions will need to be considered during the design phase.

7.3.11. Detailed settlement analyses will be undertaken as part of the GDR to determine if differential settlement between the existing culvert and culvert extension will be an issue.

Extension of Barn Farm Culvert

7.3.12. The existing Barn Farm culvert to the north of M5 J10 (Structure Key 34462) will be extended.

7.3.13. The existing culvert comprises a 1.2m diameter twin concrete pipe and it is currently planned to extend this pipe using precast concrete. Extension lengths are 7.9m to the west and 8.45m to the east. Borehole M5_BH036 was drilled at the location of the culvert and shows that the culvert extensions will be founded on weathered Charmouth Mudstone Formation which is described as stiff to very stiff in nature. The culvert extensions will be located under the new slip roads and due to the existing ground being flat at these locations only a shallow (600mm) trench will be excavated to lay the bedding material. As earthworks are laid for the slip roads, the culvert extensions will be incorporated into the main works, so excavation stability is not anticipated to be a concern. However, the loading of the culvert extensions will need to be considered during the design phase.

7.3.14. Detailed settlement analyses will be undertaken as part of the GDR to determine if differential settlement between the existing culvert and culvert extension will be an issue.

Link Road Flood Culverts

7.3.15. Two groups of flood culverts are planned to carry the Link Road across the flood plain as shown in the General Arrangement Drawings (Appendix A) and the geological long sections in Appendix C.

7.3.16. The ground conditions beneath the Northern Flood Culvert (Group 1) comprise a thin layer of Made Ground/Cheltenham Sands and Gravels underlain by stiff Weathered Charmouth Mudstone Formation. As a result, consolidation settlement is unlikely to be a problem for this group of culverts.

7.3.17. However, due to the vicinity to the River Chelt, the ground conditions beneath the Southern Flood Culvert (Group 2) comprise a 1m thickness of Alluvium. At this location, consolidation settlement is likely, and the Alluvium may need to be removed or the culverts allowed to settle as part of the site works.

7.3.18. At the time of writing this report, the invert level of the flood culverts is unknown. However, the maximum bearing pressure under the box units is estimated to be approximately 150kPa which may require the Alluvium to be dug out and replaced, ground improvement methods or micro piling.

7.3.19. Detailed settlement analyses will be undertaken as part of the GDR to confirm the above.

Northern Flood Culvert (Group 1)

7.3.20. Comprised of 19 individual box culverts placed back-to-back as follows:

- 18 No. 3m wide, 1.25m high.
- Separated in middle by 1 No. 6m wide, 2.0m high.

- Total length of Group 1 is 70.9m.
- Total area of Group 1 is 2411m^2.

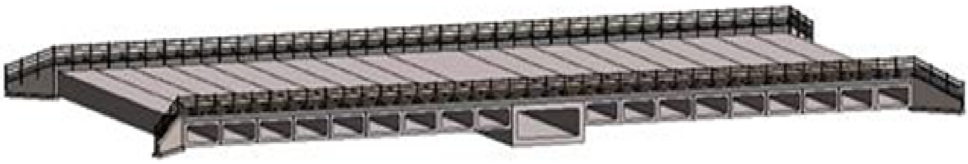

Figure 7-4 - Schematic of Proposed Northern Flood Culvert

Southern Flood Culvert (Group 2)

7.3.21. Comprised of 18 individual box culverts placed back-to-back. All culverts are 3m wide and 1.25m high with a total length of 63.9m and area of 2780m^2.

Figure 7-5 - Schematic of Proposed Southern Flood Culvert

River Chelt Bridge

7.3.22. To the south of the Link Road flood culverts, a new bridge is proposed to cross the River Chelt. This bridge will be 24.85m in length and 22.4m in width.

7.3.23. The bridge is proposed as a prestressed concrete beam superstructure with full height RC abutment walls. At the time of writing this report, the foundations are estimated to be piles of diameter 1.05m. Due to constructability issues at this location (adjacent to the river/high groundwater levels/presence of Alluvium), shallow foundations have been discounted.

7.3.24. A geological long section is given in Appendix C and shows significant variations in rockhead level between LR_BH017 and BH018. It is likely that piles will need to be founded in the Charmouth Mudstone Formation which is encountered approximately 8.5mbgl. This unit has reasonable strength and stiffness and will provide reasonable vertical and lateral pile strength and stiffness, subject to detailed design. Further information will be presented in the GDR.

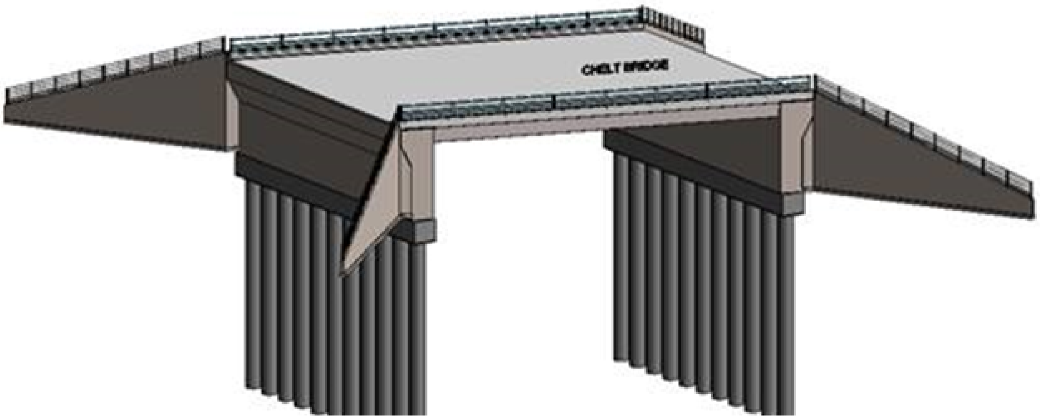

Figure 7-6 - Schematic of Proposed River Chelt Bridge

7.4. Aggressive Ground Conditions

7.4.1. The bedrock underlying the entire area within the site boundary is known to be sulphate bearing strata resulting in Thaumasite Sulphate Attack (TSA) and corrosion of buried concrete structures. Corrosion of the Piffs Elm concrete sub-structure is well documented with the ground in this area assessed to have a BRE DS-3 and ACEC-3 classification.

7.4.2. During the recent ground investigation, BRE SD1 soil aggressivity testing was undertaken to enable suitable concrete specification during design works. The testing confirmed a BRE DS-4 and ACEC-3s classification.

7.4.3. In addition, due to the aggressive ground conditions associated with the Charmouth Mudstone Formation, no material derived from this formation should be stored near or reused as backfill to concrete structures. Only Class 6N/6P Fill will be allowed for backfilling the new bridge abutments/wing walls.

7.5. Compressible Strata

7.5.1. The superficial Alluvium deposits have been logged as either a firm sandy gravelly CLAY or a fine to coarse SAND. No pockets of peat were identified during the recent ground investigation.

7.5.2. At the location of the M5 J10 Interchange and approach embankments, no Alluvium has been encountered as this material will have been removed in the 1970's as part of the original M5 construction.

7.5.3. Alluvium, however, is identified along the length of the Link Road up to 2m in thickness. In order to minimise differential settlements, outline design for the River Chelt Bridge proposes piled foundations as discussed in Section 7.3 above. Detailed settlement analyses will be undertaken as part of the GDR and Alluvium beneath the flood culverts and embankments may need to be dug out and replaced with granular fill. Alternatively, it may be preferable to build the Link Road embankments to surcharge the underlying ground which would need to be programmed into the construction works.

7.6. Presence of Hard Strata

7.6.1. The recent GI has confirmed the presence of limestone bands within the Charmouth Mudstone Formation throughout the site area. The bands are typically less than 1m in thickness, however, in borehole LR_007, a 2.95m thick limestone band was observed. The limestone bands are described as 'moderately strong' and encountered from 2.45mbgl.

7.6.2. Due to the size of piles (1.2m diameter), bored piling is the preferred option, although there will still be a risk of refusal when the hard Limestone bands are encountered.

7.7. Groundwater Levels

7.7.1. Due to a lack of existing groundwater information, fifteen standpipes were installed as part of the recent ground investigation to allow for an accurate assessment of groundwater levels over time and to understand seasonal fluctuations. Monitoring visits were undertaken monthly from August 2021 to February 2022 as discussed in Section 5.7 and presented in Table 5-1.

7.7.2. Based on information received to date:

- Groundwater levels in the vicinity of the M5 J10 Interchange vary between 0.35 and 2.43mbgl.
- Groundwater levels in the vicinity of the A4019 vary between 0.22 and 3.62mbgl.
- Groundwater levels in the vicinity of the Link Road vary between 0.11 and 5.98mbgl.

7.7.3. The high groundwater levels could cause difficulties with the stability of excavations during construction, particularly within areas of sands and gravels. If the works take place within the winter months when groundwater levels are at their highest, flooding of excavations can also be expected, and pumping may be required. High groundwater levels could also affect rotary piling and the design should consider that rotary piles may need to be cased into the Weathered Charmouth Mudstone Formation.

7.8. Material Reuse

7.8.1. At the time of writing this report, the outline earthworks design has identified a requirement of approximately 600,000m^3 of fill with 200,000m^3 of excavation which gives a required import of 400,000m^3. This figure equates to approximately 800,000T to be transported to site which is not feasible given the programme for works.

7.8.2. The recent GI has confirmed that throughout most of the site area, the weathered Charmouth Mudstone Formation is very stiff with SPTs ranging from 20 to 50+. Several of the machine excavated trial pits encountered hard ground (very stiff clay) and refused with the excavator at 3m depth indicating that the ground becomes competent at fairly shallow depth. Further details will be presented in the Geotechnical Design Report (GDR) but the weathered Charmouth Mudstone Formation has reuse potential as a Class 2 General Cohesive Fill for the Scheme, and has historically been used for the existing M5 embankments. It should be noted that once this material is excavated and stockpiled it can heave, oxidise and degrade. As a result, it will be important to consider the handling, storage and stockpiling of this material during the construction phase and the importance of this should be made clear to the contractor undertaking the works.

7.8.3. As discussed in detail in Section 7.9 below, the excavated material from the Flood Storage Area could satisfy the import requirements for the Link Road and embankments to the east of the M5. However, it should be noted that the high organic content of the Alluvium renders this material only suitable as a Class 4 Landscape Fill.

7.8.4. As discussed in Section 7.2, alternatives to earthworks are to be considered during design and will be discussed in detail in the Geotechnical Design Report (GDR). Alternatives will include the use of reinforced slopes, reinforced soil walls (green wall), reinforced soil walls (panel/block) or RC walls to create steeper slope angles and reduce import quantities. It is likely the final design will be a combination of these solutions in order to reduce the volumes of fill required for the Scheme.

7.8.5. In addition, further to information presented in Section 7.4, Charmouth Mudstone Formation should be stored away from and not utilised as backfill for concrete structures. Class 6N/6P Fill will be required for backfilling the new bridge abutments/wing walls.

7.9. Flood Storage Area (FSA)

7.9.1. Creation of the Scheme will reduce the available volume of flood storage on both the River Chelt and Leigh Brook floodplains. As a result, compensatory flood storage will be provided in the fields to the east (upstream) of the M5 motorway, immediately south of the A4019 as highlighted in Figure 7-7.

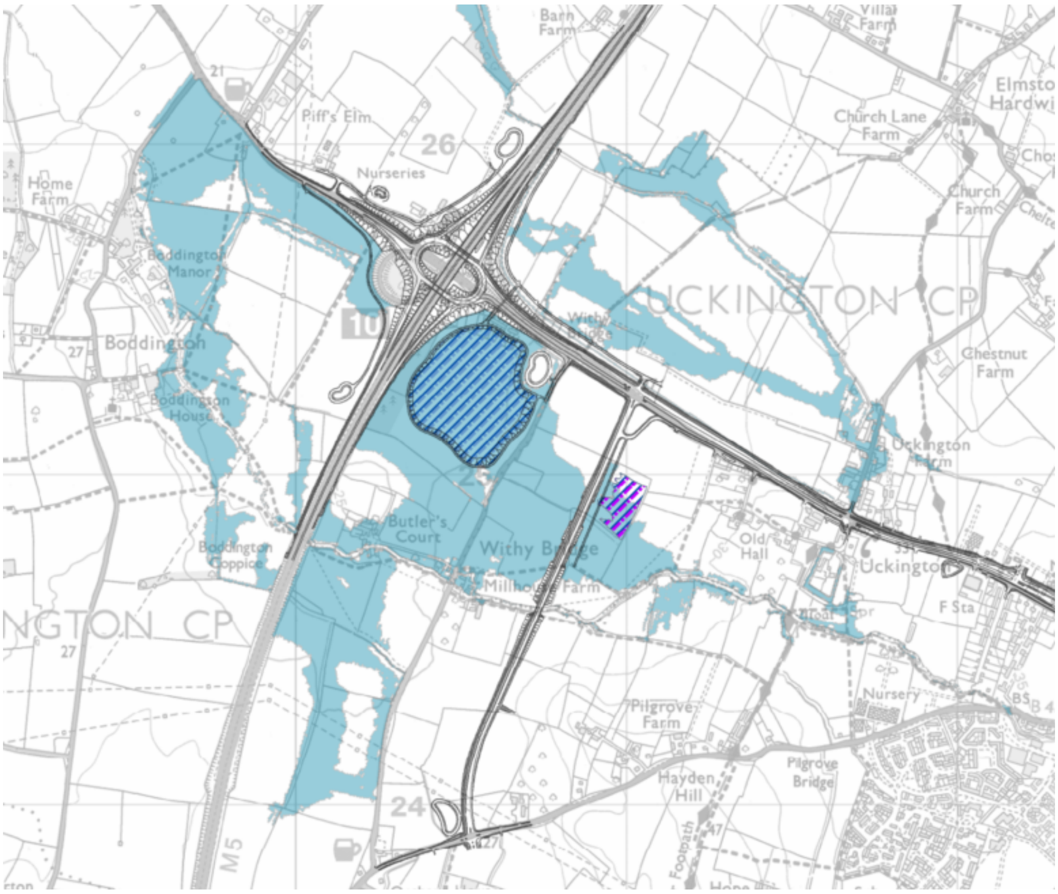

Figure 7-7 - Flood Storage Area

7.9.2. The Scheme will, therefore, provide an excavated flood storage area which may be developed as a wetland bowl. The flood storage area will drain through the existing Piffs Elm culvert and accommodates the volume of River Chelt floodwater displaced by the Scheme footprint and provides storage for the additional floodwater prevented from accessing the Leigh Brook floodplain.

7.9.3. At the time of writing this report, the outline design for the FSA includes for nominal 1 in 3 side slopes around the wetland. The design requires a total excavation below existing ground level (and hence storage volume) of 197,440m^3 (to Piffs Elm culvert invert level of 22.37mAOD). This equates to an excavated depth of ~1.5m along the western perimeter and ~3m along the eastern perimeter.

7.9.4. Five window samples were undertaken within the FSA to confirm the ground conditions (WL_WS001-005). These window samples recorded weathered Charmouth Mudstone Formation from between 1.65 – 3.65mbgl. This material was generally described as stiff to very stiff and although it is suitable for reuse as a Class 2 fill, a hard dig to excavate it can be expected. As discussed in Section 7.8, this material could satisfy the fill requirements for the Link Road and embankments to the east of the M5 which is a short distance from source to intended location. It could also be used to form Embankment No. 3 in Figure 7-1.

7.9.5. Cheltenham Sands and Gravels are observed in WS004 (0.9m) and WS005 (1.0m) at the southern end of the FSA which is different from the superficial mapping given in the BGS GeoIndex. This material was not encountered in WS001 and WS002 at the northern end of the FSA as expected.

7.9.6. All the window samples confirm the presence of Alluvium across the FSA varying in thickness between 1.45 – 2.15m. This material is described as a very soft to firm clay with gravel and roots/occasional wood fragments. Due to the organic content of the Alluvium this material would be unsuitable to form the road embankments, but it could be used as a Class 4 Landscape Fill within the Scheme extents.

7.9.7. In addition, groundwater monitoring of the standpipes installed in WL_WS002 and 004 has recorded shallow groundwater levels; between 0.39 – 0.98mbgl. Permeability testing undertaken at the base of WS003 and WS005 within weathered Charmouth Mudstone Formation resulted in permeabilities of 10^{-7}ms confirming the impermeable nature of the ground and its suitability for flood storage.

7.9.8. There are four key risks associated with the FSA which have been included in the geotechnical risk register in Table 8-2. These relate to the following:

- Instability of the existing and proposed raised / widened east bank of the M5 and south bank of the A4019 adjacent to the FSA due to rapid drawdown following impoundment of water in the FSA. During design, the D&B Contractors Designer will need to design the embankments with adequate safety margin for rapid drawdown conditions.
- Instability of the existing and proposed raised / widened east bank of the M5 and the south bank of the A4019 adjacent to the FSA due to seepage during flooding events. The FSA is currently designed with the bulk of water dissipated after 10-50hrs following a flooding event. As the embankments are comprised of clay over weathered CMF, seepage is likely to be minimal over this duration and failure unlikely. Fill materials to be specified by the D&B Designer should be chosen to ensure seepage is checked.
- Internal erosion of the existing and proposed raised / widened east bank of the M5 and the south bank of the A4019 adjacent to the FSA caused by water passing along existing features in the embankment such as drains and service ducts. There will be a requirement for the D&B Contractor to inspect the earthworks, identify potential seepage paths and undertake works to cut them off.
- Potential for contact erosion along the existing culvert. D&B Contractor will need to investigate the existing culvert surround and detail measures to cut off any potential seepage path.

7.10. Drainage Basins

7.10.1. Six drainage basins are planned as shown on the General Arrangement Drawings (Appendix A). Details for each basin are given in Table 7-1 below:

Table 7-1 - Planned Drainage Basins

Drainage Basin Location	Volume (m^3)	Depth (m)	Invert Level (m)	Cover Level (m)
West of M5 J10 on north side A4019 adjacent to Sheldon Nurseries	650	0.9	21.80	22.70
Southwest of A4019 / northern Link Road junction	6167	1.2	25.30	26.50
Northwest of B4634 / southern Link Road junction	2549	0.9	25.30	26.20
South of A4019 adjacent to Cheltenham West	2165	1.1	33.34	34.45

Drainage Basin Location	Volume (m^3)	Depth (m)	Invert Level (m)	Cover Level (m)
Community Fire Station				
West of M5 to south J10	1666	1.05	22.67	23.72
West of M5 to north J10	5897	1.2	22.06	23.26

7.10.2. During the recent ground investigation, soakaway testing was undertaken at all six locations and confirmed that the underlying ground has low permeability. All the soakaway tests failed as the water level did not drop in level for the duration of the test. As a result, the six drainage basins will be designed as Attenuation Basins.

7.10.3. All soakaway test results are presented within the Factual Fieldwork Report in Appendix D.

7.11. Pavement Design

7.11.1. As part of the recent ground investigation, 18 insitu plate load tests were undertaken, and the results are summarised in Table 7-2 below:

Table 7-2 - CBR Test Summary for Pavement Design

Scheme Location	No. Tests	Maximum CBR (%)	Minimum CBR (%)	Typical CBR (%)
M5	9	>16.4	7.0	14.0
A4019	5	>16.4	6.5	8.0
Link Road	4	11.9	1.6*	-

Notes: * Value obtained from LR_CBR003 and was only test throughout site area which recorded a CBR value lower than 4.5%. This location is at the southern end of the Link Road adjacent to the B4634

7.11.2. All CBR test results are presented within the Factual Fieldwork Report in Appendix D.

7.11.3. Preliminary pavement design is ongoing, but the results above indicate that for the M5 J10 and A4019, a foundation thickness of 150mm may be sufficient beneath the asphalt layer (270mm). However, the Link Road may require a greater foundation thickness due to lower recorded CBRs.

7.12. Contamination

7.12.1. Based on the sampling and laboratory testing undertaken, there are not considered to be potential unacceptable risks to human health or controlled waters from contaminants detected in soil / soil leachate from the site that have been collected from Made Ground soils.

7.12.2. In addition, no asbestos fibres were detected within the soil samples analysed.

8. Geotechnical Risk Register

8.1. Geotechnical Risk Register

8.1.1. A Geotechnical Risk Register has been prepared using the Geotechnical Risk Index detailed in Table 8-1 below. The geotechnical risks shown in

8.1.2. Table 8-2 below present the key hazards identified at this stage of the Scheme.

Table 8-1 - Geotechnical Risk Index

Risk Probability (P)		Risk Impact (I)		Risk Rating (R)	
1	Highly Unlikely	1	Slight Harm / Cost / Delay	1	No action required
3	Unlikely	3	Moderate Harm / Cost / Delay	9	Moderate action
5	Highly Likely	5	Extreme Harm / Cost / Delay	25	Immediate Action

Table 8-2 - Geotechnical Risk Register

Hazard	Impact	Initial Risk Rating			Mitigation Measures	Risk after Mitigation Measures			Description of Residual Hazard
		P	I	R		P	I	R	
Areas of soft and/or compressible ground (superficial deposits)	Excessive settlement or differential settlement resulting in structural damage, delays with associated costs.	4	3	12	GI has confirmed that the Alluvium present along the Link Road is either a firm sandy CLAY with gravel or a fine to coarse SAND with gravel. These deposits are only observed in the vicinity of watercourses and are generally less than 2m thick. Where embankments are	2	3	6	Settlements are not expected to be significant, but settlement analysis will be undertaken during the design stage and included in the GDR.

Hazard	Impact	Initial Risk Rating			Mitigation Measures	Risk after Mitigation Measures			Description of Residual Hazard
					required, ground improvement techniques may be necessary, or the Alluvium may be removed or surcharged.				
Flood Risk - Surface water flooding - Groundwater flooding - Flooding from rivers or sea	- Flooding of site impacting construction phases and risk to health and safety of site personnel. - Flooding and/or collapse of unsupported excavations.	4	3	12	- Site works to account for risk of flooding. - Stability of excavations to be considered with appropriate stabilisation utilised where appropriate. - Dewatering of excavations.	2	3	6	- Recent GI has confirmed that groundwater is generally shallow, within 3m from ground surface. - Flood risk will be greater during the winter months.
Aggressive soil (Charmouth Mudstone Formation) - Thaumasite Sulphate Attack to buried concrete and when used as backfill to structures	Chemical corrosion of buried concrete undermining structural integrity of assets.	5	5	25	- Recent BRE SD1 testing has confirmed DS-4 classification for concrete. - Any soil stored for reuse on site to be stored away from concrete structures. - National Highways will only accept Class 6N/6P Fill for backfilling the new bridge abutments / wing walls.	2	5	10	Low

Hazard	Impact	Initial Risk Rating			Mitigation Measures	Risk after Mitigation Measures			Description of Residual Hazard
Presence of hard Limestone bands within the Charmouth Mudstone Formation	Issues during piling - delays and associated costs.	5	3	15	The GI has confirmed the presence of hard Limestone bands within the CMF which will need to be taken into account during the design phase.	4	3	12	- Greater thicknesses of Limestone encountered than indicated by the recent GI. - Bored piling preferential to driven piles but risk remains of hard driving conditions in the Limestone.
Reuse of Charmouth Mudstone Formation as a Class 2 Fill	When dug out there is a potential for the material to oxidise, degrade and swell.	5	3	15	- Stockpile material properly. - Use material quickly i.e. compact instantly. - Avoid water percolating through the material by covering stockpiles.	4	3	12	Ensure careful handling and stockpiling to prevent degradation of fill use.
High organic content of the Alluvium	This material is not suitable to be reused as a Class 2 Fill.	5	3	15	Alluvium can be used as a Class 4 Landscape Fill within the Scheme extents.	4	3	12	
Existing earthwork stability	- Potential instability and/or failure of existing assets resulting in damage, delays and associated costs.	3	4	12	- No areas of earthwork instability were observed during the recent GI. - Earthworks should be inspected prior to site works to	2	4	8	Unexpected impacts result in instability of asset.

Hazard	Impact	Initial Risk Rating			Mitigation Measures	Risk after Mitigation Measures			Description of Residual Hazard
	- Health and safety of site personnel may be affected.				ascertain level of associated risk with mitigation measures implemented if required. - Geotechnical design and construction methodology to consider existing assets and mitigate adverse effects where possible. - Monitoring of asset may be required during site activities to ensure integrity of assets.				
Presence of Cheltenham Sands and Gravels	Likelihood of 'running sands' during excavation causing instability.	5	3	15	Avoid excavation in these areas if possible.	4	3	12	Instability of excavations.
Instability of existing and proposed raised / widened road embankments adjacent to the Flood Storage Area (FSA)	Rapid drawdown following impoundment of water in the FSA causing instability	4	5	20	D&B Designer will need to design the embankment with adequate safety margin for rapid drawdown conditions.	2	4	8	
Instability of existing and proposed raised / widened road embankments	Seepage through existing embankments during flooding	3	4	12	GI has confirmed existing wide and low embankments comprise reworked	2	4	8	

Hazard	Impact	Initial Risk Rating			Mitigation Measures	Risk after Mitigation Measures			Description of Residual Hazard
surrounding the FSA due to seepage	events could cause slope instability				local CMF so ground conditions are clay embankments over clay ground. Fill materials to be specified by the D&B Designer in proposed raised and widened embankments should also be chosen to ensure seepage is checked.				
Internal erosion of existing and proposed raised / widened road embankments adjacent to the FSA	Water passes through embankments via drains/service ducts causing local instability (currently unknown)	3	4	12	D&B Designer to ensure design does not introduce potential seepage paths. D&B Contractor will need to watch excavations into the existing embankment to identify potential seepage paths with mitigation to prevent water entering the embankment	2	4	8	
Instability of existing and proposed raised / widened road embankments adjacent to the Flood Storage Area (FSA) due to contact	Water passes through embankments at culvert location causing local instability	3	4	12	D&B Contractor will need to investigate the existing culvert surround and detail measures to cut off any potential seepage path.	2	4	8	

Hazard	Impact	Initial Risk Rating			Mitigation Measures	Risk after Mitigation Measures			Description of Residual Hazard
erosion along the existing culvert									

9. References

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Appendices

Appendix A. General Arrangement Drawings

General Arrangement drawings for the Scheme are provided in application document TR010063 – APP 2.9.

Appendix B. Geotechnical Parameter Plots

The Geotechnical Parameter Plots have not been included within this copy of the Ground Investigation Report, and are available on request.

Appendix C. Geological Long Sections

The Geological Long Sections have not been included within this copy of the Ground Investigation Report, and are available on request.

Appendix D. Factual Fieldwork Report

The Factual Fieldwork Report has not been included within this copy of the Ground Investigation Report, and is available on request.

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