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Preston & South Ribble Flood Risk Management Scheme

Geoenvironmental assessment for Areas 1 to 5

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In partnership with:

Lancashire County Council

North West Regional Flood & Coastal Committee

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Preston & South Ribble Flood Risk Management Scheme

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P01	20/10/2020	For issue	C.Cantle	S.Tavner	M.Westwood	M.Waddicor
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1. Introduction

1.1 Background

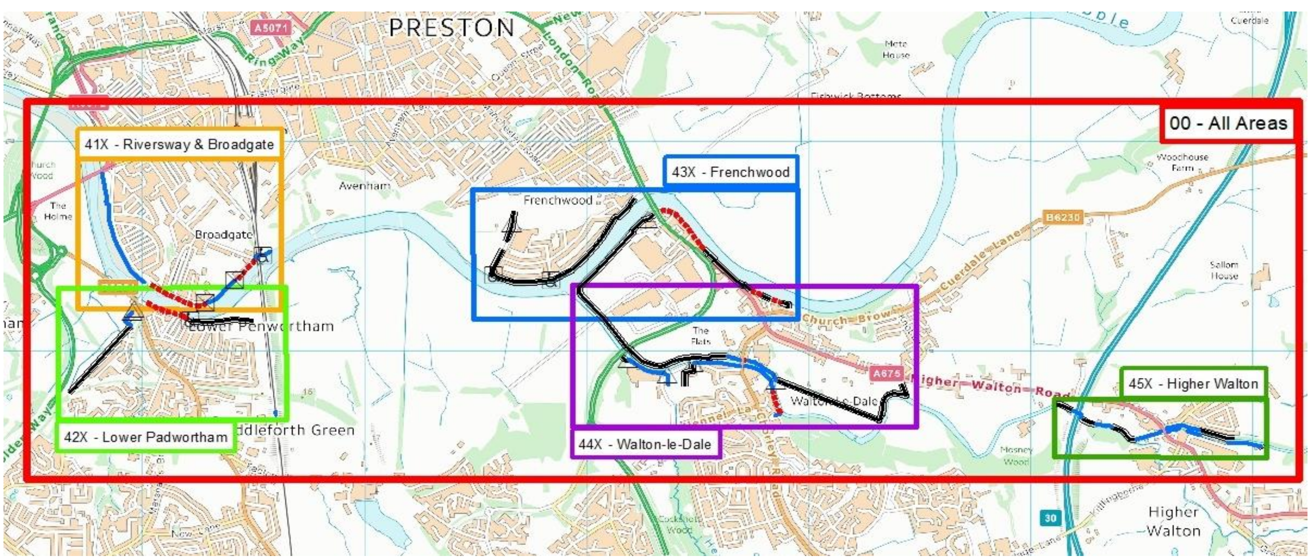
The City of Preston in Lancashire is subject to significant flood risk. The primary sources of flood risk are fluvial flooding from the River Ribble and River Darwen. Tidal surge has been assessed as unlikely to coincide with fluvial flooding. The Preston and South Ribble Flood Risk Management Scheme (FRMS) (referred to hereon in as the scheme), has been established to address the flood risk to both residential and commercial buildings.

The scheme is divided into five geographic areas, and subareas (referred to as reaches) , as detailed in the Design Philosophy Statement (Jacobs, 2020a), shown on Inset 1, and summarised as follows:

- Area 1: Riversway and Broadgate (41X) – Reaches A, B, C and D
- Area 2: Lower Penwortham (42X) – Reaches A, B and C
- Area 3: Frenchwood (43X) – Reaches A, B and C
- Area 4: Walton-Le-Dale (44X) – Reaches A, B, C, D, E and F
- Area 5: Higher Walton (45x) – Reaches A, B, C, D and E.

These areas all lie to the south of the city centre of Preston in Lancashire, within the floodplains of the rivers Ribble and Darwen, between the Liverpool Road Bridge in the west to Higher Walton in the east. In addition to the scheme overview plan, Figure 1 provides larger-scale plans presenting the proposed extent of the work and the location of the exploratory holes.

Inset 1. Preston & South Ribble scheme areas



1.2 Development proposals

The proposed flood defences comprise a range of measures which include the structures below. The assumptions in italics below have been made to inform this assessment with regards to below ground excavations.

- **Replacement or construction of new flood defence walls (concrete walls)**: *shallow excavations, assumed to be no deeper than 1 metres below ground level (mbgl) to facilitate construction of new foundations, where required.*

- **Replacement or construction of new earthwork /embankments/access ramps:** *deeper excavations, assumed to be greater than 1 mbgl, in order to construct embankment foundations, blockwork revetment etc. where required.*
- **Glass panel defences (constructed on top of concrete walls):** assumed *no below ground excavations.*
- **Flood gates:** *shallow excavations, assumed no deeper than 1 mbgl, to facilitate construction of new foundations where required.*
- **Seepage cut-off piles and sheet piles:** *shallow excavations to facilitate construction of pile mat/cap.*
- **Landscaping:** *shallow excavations, assumed less than 1 mbgl, to facilitate construction.*

The drawings presented in Appendix A provide details of the current proposals for the scheme (General Arrangement drawings), noting that detailed design is ongoing for Areas 3, 4 and 5.

Appendix B presents the environmental masterplan for Areas 1 and 2; masterplan drawings are not yet available for Areas 3, 4 or 5.

Table 1 provides a summary of the design proposals and proposed landscaping for each area, that are pertinent to the assessment within.

Table 1. Summary of design proposals

Area	Reach	Description of works	Soft landscaping
1	A	Replacement of existing concrete wall; sheet piling	Road verges with hard-standing footpaths. Grassed area in Broadgate Gardens
	B	Replacement of existing concrete wall; new concrete wall; new flood gates; stabilisation of river bank sections with blockwork revetment; seepage cut-off piles and sheet piles	Mostly road verges with hard-standing footpaths
	C	Concrete retaining wall along boundary of the existing Preston City Council compound, with two flood gates tying into the abutments of the West Coast Mainline viaduct	No soft landscaping anticipated
	D	Minor works to improve emergency access to the river via an existing slipway at the Preston Sea Cadets just downstream of Liverpool Road bridge	Existing grassed areas mostly retained; some removal of trees
2	A	New concrete wall; new footpath ramp along Golden Way footpath; raising of existing ground levels by approximately 1 m. New road ramp at entrance to Penwortham Church and within entrance to allotments. Raising of existing ground adjacent to Penwortham Residential Park.	Existing allotments to be reinstated where disturbed; landscaping of old railway bank
	B	Replacement of existing concrete wall; new river bank extended into the river with retaining wall and steel toe pile to retain new bank; replacement of embankment at Ribble Sidings	Penwortham Residential Park Area maintained with new habitat creation area in east of Reach B (Ribble Sidings); footpath verges and no soft landscaping along Riverside Road

Area	Reach	Description of works	Soft landscaping
	C	Partial infill of the Network Rail disused underpass with mass concrete	N/A
3	A	New embankment; new concrete wall; access ramps; services diversions/protections	Frenchwood Recreation Ground to west of esplanade – open space; grassed road verges adjacent to hard-standing footpath along Boulevard
	B	New embankment; new concrete wall	Footpath, shrubs, trees and grass along river bank
	C	New sheet steel pile wall and embankment	Mostly vegetated river bank with no public access; very limited soft landscaping in eastern extent around garages (King's Croft)
4	A	Raising of existing embankment; additional retaining structure from car park; partial raising of Winery Lane road as part of embankment	Footpath, shrubs, trees and grass along river bank
	B	Raising of existing embankment; replacement of concrete wall	Footpath, shrubs, trees and grass along river bank
	C	Modification of existing concrete wall; raising of existing embankment and footpath	Footpath but limited public access in places, mainly trees and grassland
	D	Existing concrete wall to be raised/replaced; short embankment; raising of existing ramps	Mostly hard-standing footpath/road with with vegetated river bank fenced.
	E	Raising of existing embankment; new concrete wall; raising of Walton Green Road with ramp; sheet pile walls; extension and raising of existing retaining walls	Mostly hard-standing footpath/road with limited vegetation in road verges
	F	New sheet piles walls	Vegetated river bank with /limited access
5	A	New embankments and concrete wall	Vegetated river bank adjacent to residential garden west of M6; vegetated river bank with no/limited public access east of M6
	B	New concrete wall and earth bund	Vegetated river bank adjacent to road
	C	New concrete wall	Vegetated river bank with no public access
	D	New concrete wall	Commercial land with no landscaping
	E	New concrete wall and embankment	Commercial land with no landscaping

1.3 Report Purpose and Scope

1.3.1 Best-practice guidance

Current best-practice guidance for the assessment of land contamination is contained in *Land contamination: risk management* (LCRM) (Environment Agency (EA), 2020), which superseded *Contaminated Land Report 11:*

Model Procedures for the Management of Land Contamination (CLR11) (Defra & EA, 2004) on 8th October 2020. LCRM identifies three core components in the assessment and management of land contamination, comprising:

- Risk Assessment (including Preliminary Risk Assessment, Generic Quantitative Risk Assessment and (if required) Detailed Quantitative Risk Assessment)
- Options Appraisal (if required)
- Remediation and Verification (if required).

1.3.2 Preliminary Risk Assessment

The Preliminary Risk Assessment element of LCRM are outside the scope of this report, and is presented in the existing reports, as follows:

- Arup desk study – Areas 1 and 2 (Arup, 2013a), Appendix C.1
- Arup WCML to M6 desk study – Areas 1, 2 and 3 (Arup, 2013b), Appendix C.2
- CH2M desk study – all areas (CH2M, 2016), Appendix C.3.

For brevity, factual information from the desk studies is summarised in Sections 2 and 3, but the reports should be referred to for more details.

1.3.3 Ground investigation

Details of the ground investigations (GIs) underpinning this assessment are summarised in Section 5. The ground investigations were designed and implemented by Arup (2012 investigation) and Mott MacDonald (2019 and 2020 investigations). Jacobs has been provided with geoenvironmental data from these investigations which are assumed to be accurate and complete; liability cannot be accepted for any omissions or errors in the data provided.

1.3.4 Gap analysis and limitations

Jacobs undertook a gap analysis of the information in March 2020, for the existing and proposed GIs for the scheme, and reached the following conclusions.

- There was generally good coverage of exploratory holes for Areas 1 and 2 with sufficient borehole depths to establish a comprehensive ground model, but two short sections were identified with insufficient data, for which additional GI was proposed and subsequently completed.
- The exploratory holes undertaken and proposed as part of the GI for Areas 3 to 5 were considered to provide good coverage.
- The specifications and factual reports for the proposed and existing GI were considered adequate with respect to geoenvironmental considerations. Piling techniques for the scheme are determined by engineering requirements, such that specific piling risk assessments are outside the scope of this report.
- Groundwater analytical testing was not undertaken as part of the 2019 and 2020 investigations and therefore assessment of any dewatering requirement is outside of this scope of this report.

During the preparation of this report, the following additional limitations have been identified.

- There is an absence of soil leachate testing for organic determinands from the 2019 and 2020 GIs.
- Asbestos quantification was not undertaken on all samples where asbestos was identified.

1.3.5 Generic Quantitative Risk Assessment

This report presents the generic quantitative risk assessments (GQRA) element of LCRM, as required to obtain planning approval for Areas 1 and 2 only.

To aid the ongoing detailed design, and in order to consolidate the assessment into one report, the GQRA for Areas 3, 4 and 5 has also been undertaken in this submission. Detailed design is ongoing for these areas and the assessment within will be required to be reviewed and updated, prior to the submission for planning approval for these areas.

1.3.6 Remediation options and material management

As a result of undertaking the GQRA, likely remediation actions are briefly discussed in Sections 7 and 9. Section 8 presents a preliminary waste classification of the site soils, should disposal to landfill of any excavated soils be required.

1.3.7 Geotechnical appraisal

This report excludes the scheme geotechnical appraisal which is contained within the following reports:

- Ground Investigation Report Areas 1 and 2 (Jacobs, 2020b)
- Ground Investigation Report Areas 3–5 and Area 2 Reach A (Jacobs, 2020c).

1.4 Report structure

The remainder of this report is structured as follows:

- Chapter 2: Site description
- Chapter 3: Environmental setting
- Chapter 4: Preliminary conceptual model
- Chapter 5: Ground investigations
- Chapter 6: Ground and groundwater conditions
- Chapter 7: Geoenvironmental risk assessments
- Chapter 8: Preliminary waste classification
- Chapter 9: Conclusions and recommendations.

2. Site description

2.1 Contemporary land use and topography

2.1.1 Areas 1 & 2

The River Ribble flows in a westerly then northerly direction through the study area, splitting it into two distinct areas: Broadgate to the north and Lower Penwortham to the south.

The banks of the River Ribble here are surrounded by a mix of terrace and semidetached housing including commercial premises in the Riverway Docklands area. Along both banks of the River Ribble are residential and commercial properties protected by an approximately 2 km long raised defence, raised ground or embankment. There are also garden allotments, wooded areas and playing field predominantly to the east of the site. The West Coast Mainline runs north to south through the eastern extent of the study area.

Topographic survey information (Mott MacDonald, 2019) shows the riverbank level to be between 5 m and 7 m above ordnance datum (AOD) and is relatively flat in the flood plain. Existing embankments, and masonry and concrete walls align the river. The bed of the River Ribble is at approximately 0 m AOD.

2.1.2 Areas 3 & 4

The Frenchwood residential area lies on the north bank of the River Ribble here, with the Capital Business Park on the south bank. Along the River Darwen through Walton-Le-Dale, the north bank comprises primarily commercial and agricultural buildings whilst the south bank comprises primarily residential property. There are a number of road bridges, including the A6 crossings of the River Ribble and River Darwen, and the B6258 crossing of the River Darwen.

Topographic survey information (Mott MacDonald, 2019) shows ground level to be between 7 m and 9 m AOD in this area along the river bank and to be relatively flat in the floodplain. Existing embankments, and masonry and concrete walls align the river. The bed of the River Ribble is at approximately 0 m AOD.

2.1.3 Area 5

This area is located in higher Walton. The River Darwen meanders approximately east to north, splitting the study area in two. Both banks comprise a mixture of residential, commercial and industrial buildings. The M6 crosses the River Darwen through the western extent of the area. Topographical survey information is not currently available for Area 5.

2.2 Site history

2.2.1 Areas 1 & 2

Previous desk studies for the scheme should be referred to for full details (Arup, 2013a; 2013b), but the site history can be summarised as below.

- Land use has primarily comprised residential, playing fields and allotments throughout the area's history.
- The West Lancashire Railway (renamed 'Southport and Preston Line' by 1912) ran from southwest to northeast through the centre of the area from the earliest historical maps reviewed, through to around 1968 when it was dismantled. The railway crossed the River Ribble adjacent to Old Penwortham Bridge. A disused railway embankment remains today.

- Liverpool Road was constructed in 1931 and crosses the River Ribble over Penwortham New Bridge at the northern boundary of Area 1 Reach A.
- A pipe bridge was constructed across the River Ribble by 1958, adjacent to the railway viaduct and Penwortham Bridge; this still exists and reuses the abutments of the old railway bridge.

2.2.2 Areas 3 and 4

The site history is summarised as below. However, the desk studies for this area (CH2M, 2016) and Arup (2013b) should be referred to for full details.

- The early site history comprised primarily agricultural land.
- Significant development started along the River Ribble in the 1930s and along the River Darwen in the 1960s, primarily comprising mainly residential property, with commercial development mainly centred around the area now known as Capital Business Park.
- Former gasworks and gasometer in Area 3 on south bank of Ribble adjacent to London Road bridge – children’s nursery now located over part of the area.

2.2.3 Area 5

The desk study for this area (CH2M, 2016) should be referred to for full details, however the site history is summarised as below.

- The early site history comprised primarily agricultural land.
- Significant development started along the River Darwen in the 1960s and has included mainly residential properties and warehouses.

3. Environmental setting

3.1 Published geology

The published geology of the site was reviewed with reference to the British Geological Survey's (BGS, 2012) *Bedrock and Superficial 1: 50,000 Map Series Sheet 75 – Preston* and BGS (2020) *GeoIndex*.

3.1.1 Artificial geology

Made ground is only shown in the Frenchwood residential area (Area 3 Reach A), the Capital Business Park (Areas 3/4), and along the north bank of the River Darwen in Walton-Le-Dale (Area 4). However, the historical land uses, built development, and also the land raising that is likely to have occurred along the river banks indicate that, made ground is likely to be present more widely than identified in the published geology.

3.1.2 Superficial deposits and hydrogeology

The geological mapping indicates the superficial deposit across the scheme areas to comprise the below.

- **Alluvium –** shown along the alignment of the River Ribble and the River Darwen. Alluvium is generally described as soft to firm normally consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel.
- **River Terrace Deposits –** located predominantly along the south bank of the River Ribble and on the north bank within the inside of a meander of the river in Areas 1 and 2. In addition, another area is shown on the north bank of the River Darwen in Area 5. The river terrace deposits are identified as comprising sand and gravel with localised lenses of silt, clay or peat.
- **Glacial Granular –** this unit comprises, Glaciofluvial and Hummocky deposits, shown to the north of River Ribble in Areas 3 and 4 and in Walton-Le-Dale in Area 5. The unit is indicated to comprise sand and gravel of glacial origin with lenses of silt, clay or organic material.
- **Head deposits –** shown to be present on the north bank of the River Ribble in Areas 3 and 4, comprising gravel, sand and clay with localised lenses of silt, peat and organic material depending on the original source materials and distance from source.

The granular portions of the superficial deposits are designated by the EA as a Secondary A aquifer.

3.1.3 Bedrock geology and hydrogeology

The BGS mapping shows the majority of the scheme area is underlain by sedimentary rock of the Sherwood Sandstone Group generally composed of sandstone with subordinate mudstone and siltstone. The underlying Sherwood Sandstone bedrock is identified as a Principal Aquifer. None of the scheme areas are within a source protection zone.

3.2 Hydrology

The River Ribble flows through Areas 1 to 3 in an east to west direction, the main river channel typically being 60 m to 100 m wide. Scheme Areas 4 and 5 are situated along the River Darwen, which flows in a south east to north west direction before it converges with the River Ribble. The River Darwen channel is typically 15 m to 20 m wide.

4. Preliminary conceptual model

Based on the desk study information and the development proposals, Table 2 presents Jacobs' summary of the preliminary conceptual model and potential pollutant linkages.

Table 2. Potential pollutant linkages

Source	Potential contaminants	Pathway	Receptor
Made ground resulting from historical land uses, built development and import of materials with unknown provenance to facilitate land raising adjacent to river corridors.	Most likely potential contaminants given the sources include heavy metals, asbestos, organic compounds e.g. PAHs, inorganic compounds e.g. ammoniacal nitrogen, and ground gases e.g. methane, carbon dioxide and VOCs	Ingestion, inhalation and/or dermal contact	Construction workers
		Ingestion, inhalation and/or dermal contact (where hard-standing or overlying clean soils are absent)	Site users (members of the public)
		Wind-blown migration of contaminants (e.g. asbestos) followed by inhalation	Adjacent land users (e.g. nearby residents)
		Vertical and lateral migration of leachable contaminants into groundwater and surface waters	River Ribble
			River Darwen
			Secondary A Aquifers (granular superficial deposits)
			Principal Aquifer (Sherwood sandstone)
		Migration and accumulation of explosive or asphyxiating gases	Adjacent land users (e.g. nearby residents)
			Buildings

Pollutant linkages relating to ground gases on site have been discounted as there are no buildings proposed as part of the scheme. Furthermore, health and safety planning would consider any excavations as confined spaces, which would mitigate any potential risks to construction workers from gases in excavations and would also apply to any small enclosed spaces included in the designs.

Assessments of aggressive ground conditions and associated risks to buildings are covered within the Ground Investigation Reports for the scheme (Jacobs, 2020b; 2020c).

5. Ground investigations

The available ground investigation data have been used as the basis for undertaking evaluation of the potential pollutant linkages identified in Table 2. This section provides an overview of the relevant GI, with the exploratory hole locations shown on Figure 1. The factual reports from all the relevant GIs are presented in Appendix D. Section 1.3.4 should be referred to for a summary of the gap analysis previously completed for the GI works.

5.1 Areas 1 and 2

GI locations within Areas 1 and 2 were undertaken in the following works (note that no GI data are available for Area 2 Reach C).

5.1.1 White Young Green (WYG) 2012

This GI was designed by Arup and undertaken in April 2012 with the factual report issued in May 2012. The GI locations included the following:

- 3 no. cable percussive boreholes (BH101-103)
- 4 no. trial pits (TP101-104)
- 2 no. window sample holes (WS103 and 105).

The exploratory hole locations were primarily located in 2 areas, one at the northern end of Area 1 and one on the southern bank of the River Ribble at the eastern end of Area 2.

Soil and soil leachate samples were variably submitted for a suite of analysis including metals, inorganic substances, polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons and semi volatile organic compounds (SVOCs). Asbestos was also analysed for in the total soil samples.

Borehole groundwater samples were also submitted for a suite of analysis including metals, inorganic substances, PAHs, petroleum hydrocarbons and SVOCs, but these data are considered too old to be suitable for assessment within the GQRA.

Three rounds of gas monitoring were undertaken for the 5 no. boreholes.

The laboratory certificates, showing the full suites are included in the factual report in Appendix D.1.

5.1.2 AEG 2019

This GI was designed by Mott Macdonald and carried out by Allied Exploration and Geotechnics (AEG) between March and June 2019. The GI covered a larger area than Areas 1 and 2 covered in this report but included the following exploratory holes relevant to Areas 1 and 2:

- 7 no. cable percussive boreholes (BH27-1, BH27-2, BH28-1, BH56-1, BH57-1, BH57-2 and BH58-1)
- 4 no. rotary coring follow on drilling from the CP holes (BH27-1, BH28-1, BH57-2 and BH58-1)
- 22 no. hand-dug pits.

Soil and soil leachate samples were variably submitted for a suite of analysis including metals, inorganic substances, PAHs, petroleum hydrocarbons and SVOCs. Soil samples were also scheduled for asbestos testing.

The laboratory certificates, showing the full suites are included in the factual report in Appendix D.2.

5.1.3 IFA 2020

Between 4th May and 12th June 2020, a scheme specific GI was carried out by IFA on behalf of Mott Macdonald; the GI primarily covering Areas 3 to 5 (see below). However, 12 locations were also included within Area 2 as follows:

- 1 no. borehole (BHA1)
- 2 no. window sample holes (WSA-1 and WSA-2)
- 2 no. trial trenches (TTA-1 and TTA-2)
- 6 no. hand-dug pits.

Soil and soil leachate samples were variably submitted for a suite of analysis including metals, inorganic substances, PAHs, petroleum hydrocarbons and SVOCs. Soil samples were also scheduled for asbestos testing.

The laboratory certificates, showing the full suite are included in the factual report in Appendix D.3.

5.2 Areas 3, 4 and 5

Exploratory hole locations within these areas were undertaken entirely during the scheme specific GI carried out by IFA (refer IFA 2020 above), between 4th May and 12th June 2020.

The GI comprised the following:

- 1 no. cable percussive borehole
- 11 no. cable percussive boreholes with rotary core follow-on
- 32 no. window sample holes
- 2 no. inspection pits
- 2 no. hand-dug trial pits
- 15 no. trial pits
- 3 no. dynamic probe holes undertaken using super heavy probing equipment.

Soil and soil leachate samples were variably submitted for a suite of analysis including metals, inorganic substances, PAHs, petroleum hydrocarbons and SVOCs. Soil samples were also scheduled for asbestos testing.

6. Ground and groundwater conditions

The ground and groundwater conditions described below are based on the GIs described in Section 5. The GI data generally confirm the stratigraphy given in the published geology.

The following presents only a summary of the strata encountered. Cross sections produced as part of the Ground Investigation Reports for the scheme (Jacobs, 2020b; 2020c), to aid in the design of the flood defences, are included in Appendix E. Note that the cross sections for area 3, 4 and 5 are currently draft versions, included only for information. The cross sections should be referred to for the detailed information regarding the interpretation, thickness and distribution of the strata described below.

6.1 Areas 1 and 2

6.1.1 Made ground

Made ground is recorded across both the scheme areas on the north and south banks of the River, with an average thickness of 1.2 m (minimum 0.15 m, maximum 3.5 m). The made ground is almost exclusively granular and was likely placed during the construction of the existing flood defences, roads and adjacent housing. The made ground frequently includes ash, clinker, tarmacadam brick, glass, tile fragments and concrete.

6.1.2 Superficial Deposits

Alluvium, river terrace, and glaciofluvial deposits are identified as comprising the superficial geology. The deposits are all identified as been primarily granular. However, cohesive alluvium was encountered in Area 2 Reach A.

6.1.3 Bedrock

The bedrock in both areas was confirmed as comprising Sherwood Sandstone, encountered typically from 4.5 mbgl to 8 mbgl.

6.2 Area 3

6.2.1 Made ground

Made ground was encountered in all the reaches, with an average thickness of 2.4 m (minimum 0.3 m, maximum 7.15 m) and was primarily granular in nature except for Reach B where cohesive made ground was prevalent. The made ground was noticeably less thick (0.3m) in Reach A (Frenchwood) recreational area, largely comprising topsoil. The made ground was noticeably thicker on both sides of the River Ribble near the London Road bridge.

The made ground comprised a combination of reworked natural granular materials (primarily sandstone and limestone) and anthropogenic materials primarily comprising brick, concrete, ceramics and glass. Ash and clinker were also frequently identified. In addition, slag and coal fragments were occasionally recorded.

6.2.2 Superficial deposits

The superficial geology comprised granular alluvium and granular glaciofluvial deposits, the alluvium typically overlying the glaciofluvial sands and gravels.

6.2.3 Bedrock

The bedrock was confirmed as comprising Sherwood Sandstone, typically encountered at 6 m to 8 mbgl.

6.3 Area 4

6.3.1 Made ground

Made ground was encountered in all the reaches, with an average thickness of 1.6 m (minimum 0.2 m, maximum 3 m)and was primarily cohesive in nature except for Reaches D and E where granular made ground was also encountered.

The cohesive made ground typically comprised firm to soft gravelly and sandy clay. The gravels comprised a mixture of natural (typically sandstone, limestone and mudstone) and anthropogenic materials comprising brick, concrete and ceramics.

The granular made ground comprised clayey gravels. The gravels typically consisted a mixture of natural materials (sandstone, limestone and mudstone) and anthropogenic materials (brick, concrete, glass and ceramics). Ash and clinker were only rarely encountered.

6.3.2 Superficial deposits

Granular alluvium, and granular glaciofluvial deposits were identified as comprising the superficial geology, with the alluvium typically overlying the glaciofluvial sands and gravels. Lenses of cohesive alluvium and possible glacial till were also identified.

6.3.3 Bedrock

The bedrock was confirmed as comprising Sherwood Sandstone, typically encountered at 7 m to 9 mbgl.

6.4 Area 5

6.4.1 Made ground

Made ground was encountered in all the exploratory holes, with an average thickness of 1.5 m (minimum 0.15 m, maximum 3.3 m). The made ground was predominantly granular, comprising a mixture of natural (typically sandstone, limestone and mudstone) and anthropogenic materials (brick, concrete and ceramics). Slag ash and clinker were only occasionally identified.

6.4.2 Superficial deposits

Granular/cohesive alluvium, and granular glaciofluvial deposits were identified as comprising most common superficial lithologies. However, in Reaches B and C glacial till comprising clay was encountered overlying the bedrock.

6.4.3 Bedrock

The bedrock was confirmed as comprising Sherwood Sandstone, and was encountered at 2.8 m to 8 mbgl; the shallower depth to rock being in the centre of Reach A. However, it is also noted that bedrock was not proven at a depth of 8 mbgl in Reach B.

6.5 Visual and olfactory evidence of contamination

Visual/olfactory observations of contamination during the GI, for example odours or evidence of free products such as oils or hydrocarbons, unusual colours or potential asbestos/asbestos containing materials (ACMs), was limited to the below.

- **Area 3 Reach A:** WS26-4 – 'strong hydrocarbon odour' noted at 4.9 mbgl in made ground with brick and clinker.
- **Area 4 Reach A:** WS40-2 – 'possible asbestos' recorded between 1.9 m and 2.2 mbgl (note that asbestos fibres were identified in a laboratory sample from 2.0 mbgl, see Section 7.1.2).
- **Area 4 Reach C**: WS36-4 – 'occasional hydrocarbon odour noted' in organic silt material between 2.6 m and 4.1 mbgl, and below 3.00 m "becomes dark grey with a strong hydrocarbon odour present".

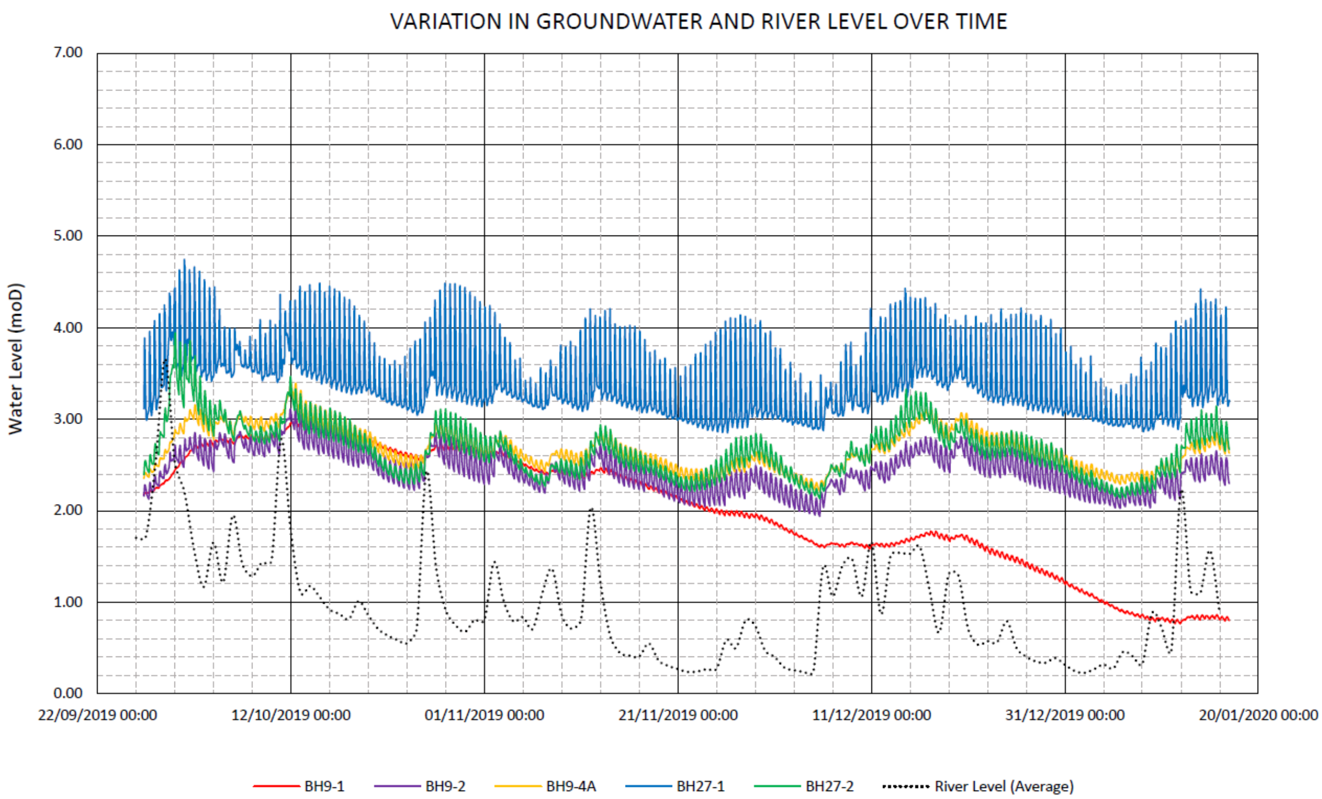
In addition, 46 out of 154 on-site PID tests were above the LOD, the majority at less than 1 ppm, but 9 between 1 ppm and 3.4 ppm. The highest readings were 3.5 ppm in WS36-4 at 3.5 mbgl, corresponding to where a hydrocarbon odour was noted above, and 3.4 ppm in WS26-2 at 1.2 mbgl, within made ground with ash, clinker and slag.

6.6 Groundwater

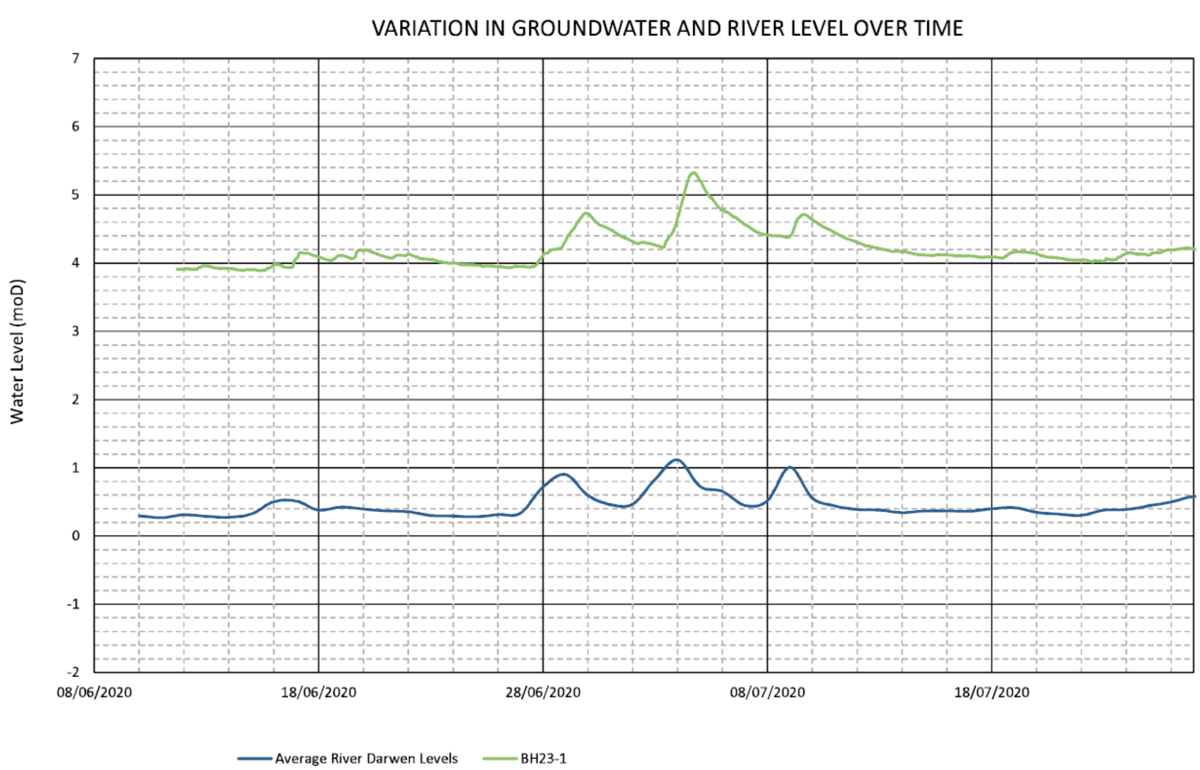
As part of the IFA (2020) GI, groundwater level loggers were installed into selected monitoring installations covering most of the scheme areas, except Area 5 (Reach C).

Insets 2 and 3 below present graphed data comparing monitored groundwater levels against the respective river levels in two of the areas, one on the River Ribble and another on the River Darwen. These were produced as part of the Ground Investigation Reports for the scheme (Jacobs 2020b; 2020c).

Inset 2. River Ribble comparison of groundwater and river levels (Area 1 Reach A).



Inset 3. River Darwen comparison of groundwater and river levels (Area 4 Reach F).



The groundwater data for both rivers indicate that superficial groundwater is in hydraulic continuity with the respective rivers as would be expected given the predominantly granular nature of the superficial deposits across the entire scheme area. Furthermore, the diurnal changes in groundwater levels in Area 1 Reach A (Inset 2) illustrate the tidal influence in this stretch of the river and further indicates the hydraulic continuity between the groundwater and the river.

Table 3 below presents typical depths to groundwater based the continuous groundwater monitoring records for selected reaches in all the scheme areas. With reference to Table 3 it is observed that groundwater is generally lower along the River Ribble (2.0 m to 3.0 mbgl) when compared to the River Darwen (3.6 mbgl to 5.4 mbgl).

In general, the data confirm that groundwater is present in the granular superficial deposits, identified as a Secondary A Aquifer. Given the lack of an aquitard (e.g. cohesive clays) below the superficial deposits, there is also assumed to be hydraulic continuity between the Secondary A Aquifer and underlying Sherwood sandstone, Principal Aquifer.

Table 3. Average depths to groundwater for selected reaches in each scheme area

Area and Reach(es)	Date Range	Groundwater level (m AOD)	Ground level (m AOD)	GW depth (mbgl)
Area 1 Reach A	26/09/2019 to 16/01/2020	3.8	6.0	2.2
Area 1 Reaches B and C	04/10/2019 to 16/01/2020	4.0	7.0	3.0
Area 2 Reaches B and C	26/09/2019 to 16/01/2020	5.0	7.0	2.0
Area 3 Reach A	10/06/2020 to 29/07/2020	4.7	9.0	4.3
Area 3 Reach B	11/06/2020 to 29/07/2020	4.1	9.5	5.4
Area 4 Reach B	11/06/2020 to 29/07/2020	4.6	9.5	4.9
Area 4 Reach F	11/06/2020 to 29/07/2020	4.2	9.0	4.8
Area 5 Reach B	10/06/2020 to 29/07/2020	11.6	15.2	3.6

7. Geoenvironmental risk assessments

7.1 Human health

7.1.1 Introduction

For assessment of chronic risks to human health, soil chemical results were directly compared to published human health assessment criteria derived in accordance with EA recommended guidance. Suitable-for-use levels (S4ULs) were used in preference to Category 4 Screening Levels (C4SLs) where available, based on a public open space (park) land use and 1 % organic matter. The use of public open space (park) criteria represents a conservative assessment for areas where public access is limited or play areas are limited for children; this is discussed further within the sub-sections which follow. An assumption of 1 % organic matter also represents a conservative assessment, as total organic carbon data indicate higher levels of organic matter in most of the soils; 1 % has been retained due to variability in the data and the limited number of locations with data.

Screening has been conducted, but not reported, against public open space (residential) GACs, and no GAC exceedances were identified in proximity to residential areas (e.g. Penwortham Residential Park Area) for any determinands.

Assessment of human health risks from asbestos within soils was undertaken via screening of all soil samples for the presence of asbestos fibres and asbestos quantification where fibres were identified through visual screening.

Appendix F provides the full results of screening, including details of the relevant human health generic assessment criteria (GACs) used. The factual reports should be referred to for the original laboratory certificates of results.

The limited analytical results from the White Young Green (2012) GI were only available in pdf format, such that they have not been incorporated into the screening, as agreed with the client. However, they have been reviewed and are discussed in the results section.

7.1.2 Results: GQRA

Table 4 summarises the GAC exceedances which have been identified and Figure 1 shows their locations.

Table 4. Summary of human health GAC exceedances

Determinand	No. GAC exceedances	Scheme Area(s)	GAC (mg/kg)[1]	Maximum concentration (mg/kg)[1]
Metals				
Asbestos	1	5	0.001 %	0.864 %
Barium	1	3	1,300	1,310
Lead	1	2	1,300	2,230
Organics (PAHs)				
Benz(a)anthracene	1	1	110	132
Benzo(a)pyrene	12	1, 2	11	75.6

[1] Unit mg/kg unless otherwise stated.

Determinand	No. GAC exceedances	Scheme Area(s)	GAC (mg/kg)[1]	Maximum concentration (mg/kg)[1]
Benzo(b)fluoranthene	12	1, 2	13	125
Chrysene	1	1	93	112.4
Dibenz(a,h)anthracene	18	1, 2, 5	1.1	17.3

Asbestos (amosite and/or chrysotile) was identified from laboratory visual screen in 7 samples within Areas 4 and 5, mainly as loose fibres, but in rope at IP05-1 and cement at TT05-3. However, quantification of asbestos fibres was only undertaken for 4 of these samples, such that asbestos fibres may be present above 0.001 % at all locations. It is not known why the samples were not subject to asbestos quantification.

It should be noted that a number of VOCs and SVOCs were detected in samples, generally at relatively low concentrations. These results have been screened against GACs where applicable in Appendix F, with no exceedances identified, but there are a number of determinands for which GACs are not available.

Soil and soil leachate results from the White Young Green (2012) investigation were subject to review against the screening criteria, and the results are comparable to the tabulated results above for Areas 1 and 2, with a number of exceedances of PAH GACs. No asbestos was detected.

7.1.3 Summary

In summary, the results of the human health GQRA indicate that there are potential risks to human health from inorganic and organic contaminants in site soils. Interpolations of the extents of the made ground associated with the exceedances have not been undertaken, but the following is noted from the results.

- **Area 1, 2 and 5.** PAH GAC exceedances are widespread in the made ground within Area 1, localised GAC exceedances were identified in Area 2, and 1 exceedance was recorded in Area 5 (in BH05-3). No PAH GAC exceedances were recorded in Areas 3 or 4. The widespread PAH exceedances are related to the presence of ash, clinker and coal fragments in the made ground, typical of the historical land use in the area.
- **Areas 2 and 3:** lead and barium GAC exceedances have been identified in Areas 2 and 3 respectively.
- **Areas 4 and 5:** asbestos fibres have been identified in several samples.
- Sample depths at which exceedances were recorded ranged from 0.2 mbgl to 1.0 mbgl across all areas.
- There are large areas within Areas 2, 3, 4 and 5 where no GAC exceedances have been identified, which appears to be due to differences in the composition of the made ground (e.g. less ash and clinker).

7.1.4 Risk evaluation

Following the GQRA, the locations where the exceedances were recorded have been reviewed for each scheme area with respect to current and future land use, and the development proposals (refer to Table 1) in order to determine if the materials represent a risk to current/future site users.

7.1.4.1 Area 1

PAHs (12 locations) and one lead concentration (in WS57-3) exceeded the GACs in the made ground. However, for the majority of the area the only ground not currently or proposed to be under hard-standing is in road verges adjacent to footpaths, where pathways to future site users from soils would be very limited such that the risks are considered negligible.

At Broadgate Gardens, east of Liverpool Road, a grassed area is present that will be retained and where exposure would be greater. However, GAC exceedances have only been recorded in IP27-2, at 0.5 mbgl, and no exceedances were recorded in a sample from 0.2 mbgl at the same location. Provided that the soils are maintained *in situ*, any risks to future site users are considered negligible.

At Preston Sea Cadets, a single marginal exceedance of the dibenz(a,h)anthracene GAC was recorded (1.50 mg/kg vs. 1.10 mg/kg GAC) in a sample from IP56-1 at 0.2 mbgl. A replacement concrete slipway and access are proposed here, with an existing grassed area maintained around this. Given the single marginal failure, inherent conservatism in the derivation of the GAC and the land use, it is considered that the risks to future site users in this area are negligible.

7.1.4.2 Area 2 (Reach A)

PAH GAC exceedances have been recorded in 2 samples from WSA-1 at 0.5 mbgl and 1.0 mbgl adjacent to Penwortham Methodist Church within the entrance to the allotments. However, the development proposal is for the ground level to be raised in this area, and as such, assuming clean imported fill is used, this would mitigate any potential human health pathways.

It is also recommended that the existing soils be left *in situ* beneath imported fill. If excavated there would be limitations on the reuse of these soils.

7.1.4.3 Area 2 (Reach B)

One marginal dibenz(a,h)anthracene GAC exceedance has been recorded (1.41 mg/kg vs. 1.10 mg/kg GAC in IP28-1). This area is associated with a flood defence wall construction/upgrade. There are assumed to be no exposure pathways to future site users where these works are completed as there is hard-standing (footpath/road) and no landscaping where public access is possible, such that this marginal GAC exceedance is not considered to present a viable risk.

7.1.4.4 Area 3 (Reach A)

One marginal barium GAC exceedance has been identified (1,310 mg/kg vs. 1,300 mg/kg GAC in BH26-1), where a flood defence wall would be installed/upgraded. However, contact with site soils would be very limited since public access is limited to a hard-standing footpath with a grass road verge adjacent, such that this marginal GAC exceedance is not considered to present a viable risk.

7.1.4.5 Area 4

Asbestos fibres were recorded through visual inspection, but not quantified, in two samples to the east and west of Chorley Road (Reaches B and F). However, there is no formal public access to these areas such that there should be no exposure route to future site users assuming the soils are left *in situ*; acute risks would be posed from this asbestos during construction.

7.1.4.6 Area 5

A marginal exceedance of the dibenz(a,h)anthracene GAC was recorded (1.44 mg/kg vs 1.10 mg/kg GAC) in BH05-3. This location is within a trade park where contact between future site users and soils would be limited and a commercial/industrial scenario is more applicable for the GAC, against which there is no exceedance (3.5 mg/kg GAC).

There is one sample (from TT05-3), where asbestos fibres were recorded above the laboratory limit of detection, and another (from IPI05-1) where asbestos fibres were identified through visual inspection but not quantified.

The sample from TT05-3 is within a river embankment adjacent to a road with no formal public access and the sample from IP05-1 is shown to be within an area of hard-standing. Provided that these soils are left *in* situ, with hard-standing maintained where IP05-1 is located, there should be no exposure pathway to future site users. However, acute risks are possible during construction, due to the identification of asbestos fibres.

7.1.4.7 Summary

Given the above evaluation, it is considered that there are no unacceptable risks to future site users from site soils, provided that:

- **Area 1 Reach A:** soils within Broadgate Gardens are left *in situ*
- **Area 2 Reach A**: soils adjacent to Penwortham Methodist Church are left beneath any imported fill for the proposed raising of ground level
- **Area 4 and 5:** with respect to asbestos, isolated detections were recorded which are considered to present potential risks to future site users or adjacent land users, if the materials are exposed, excavated and/or reused.

There may be potential acute risks to construction workers due to the presence of asbestos fibres in some locations within Areas 4 and 5, and the extents of ACMs in the vicinities of the detections are unknown.

7.2 Controlled waters

7.2.1 Introduction

The risk assessment for controlled waters from the site soils has been undertaken by evaluation of total soil and soil leachate testing undertaken within the scheme area. This controlled waters risk assessment, is based primarily on the following guidance:

- *Remedial Targets Methodology (RTM): Hydrogeological Risk Assessment for Land Contamination* (EA, 2006a)
- *The Environment Agency's approach to groundwater protection* (EA, 2018)
- *Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies* (CL:AIRE, 2017).

For the soils leachate data, environmental quality standards (EQSs) have been used in preference to drinking water standards (DWSs) where available. For certain metals, the bioavailable fractions have been calculated using *Metal-Bioavailability Assessment Tool (M-BAT)* (WFD-UKTAG, 2014). Appendix F provides the full results of screening, including details of the relevant water quality standards (WQSs) used. The factual reports should be referred to for the original laboratory certificates of results.

The risks from organic substances (primarily hydrocarbons and PAHs) have been evaluated through consideration of the total soils chemical results and GI data, including visual and olfactory evidence of hydrocarbon contamination.

Groundwater analytical results were only available from the White Young Green (2012) GI (6 samples), but were only available in pdf format to Jacobs at the time of writing. As such due to the limited volume and age of these data, they have not been considered in the assessment, as agreed with the client.

7.2.2 Leachate testing

Table 5 summarises the WQS exceedances identified. Figure 1 shows the locations where WQS exceedances have been recorded.

Table 5. Summary of WQS exceedances

Determinand	No. WQS exceedances	Scheme Area(s)	WQS (mg/l)[2]	Maximum concentration (mg/l)[2]
Antinomy	18	2, 3, 4, 5	0.005	0.055
Ammoniacal nitrogen as N	8	1, 2, 3, 4	0.39	7.58
Barium	1	3	0.7	1.04
Cadmium	2	3	0.00015	0.004
Chromium	1	2	0.05	0.139
Chromium III	2	1, 2	0.0047	0.008
Chromium VI	8	1, 2	0.0034	0.131
Copper	14	1, 2, 3, 4, 5	0.02	0.254
Cyanide	3	1, 2, 3	0.001	0.01
Cyanide (complex)	1	3	0.001	0.03
Cyanide (free)	4	1, 2	0.001	0.03
Fluoride	3	1, 2, 5	1.5	2.14
Iron	5	2, 3, 4, 5	1	5.11
Lead	17	1, 2, 3, 4, 5	0.007	0.445
Magnesium	19	1, 2	0.05	14
Manganese	10	1, 2, 3, 4, 5	0.15	0.438
Nickel	2	3	0.01044	0.101
Vanadium	2	1, 5	0.02	0.038
pH	5	1, 2, 4	6 to 9 pH	5.79 (min pH) 11.5 (max pH)
Phenol	5	1, 2	0.0077	0.033
Zinc	9	1, 2, 3, 4, 5	0.03	0.210

The results show widespread exceedances of inorganic WQSs in soil leachate, throughout made ground across the scheme areas and with no particular geospatial pattern.

[2] Unit mg/l unless otherwise stated

7.2.3 Theoretical partitioning of soil-phase organic determinand concentrations

Leachate testing for organic determinands was only undertaken for 2 samples as part of GI. Therefore, in accordance with EA guidance (EA 2006a), the risks from organic substances in soils have been assessed by undertaking an RTM Level 1 total soils assessment for organic determinands. *Hydrogeological Risk Assessment for Land Contamination. Targets Worksheet v3.2* (EA, 2006b) has been used to calculate the theoretical soil-phase concentrations for several potential contaminants of concern (CoCs) which may breach the EQSs in groundwater, i.e. the remedial targets (RTs).

Five CoCs were selected for assessment, namely: anthracene, benzene, benzo(b)fluoranthene, naphthalene and toluene. The CoCs were selected based on a review of organic soil concentrations for hydrocarbons (aliphatic and aromatic banding and BTEX) PAH compounds, and consideration of soil descriptions obtained from GI.

Review of the analytical data indicates that PAHs are the principal risk driver, associated with the majority of the elevated speciated hydrocarbon results, and also being associated with low EQS values. This observation is supported by exploratory hole logs, which indicate that ash and clinker are present in the made ground, which are typically responsible for the presence of PAHs. Furthermore, the lack of visual and olfactory identification of hydrocarbons such as free phase product, indicates petroleum fuels and oils are unlikely to be present.

Five specific CoCs have been chosen as marker compounds to represent the full range of BTEX and PAH compounds, taking into account their equivalent carbon numbers and relative solubilities and mobilities in groundwater as summarised in CL:AIRE (2017).

Site-specific data were used for fraction of organic carbon and natural moisture content within the theoretical soil-phase concentration calculations, with water- and air-filled porosities calculated using the RTs worksheet (EA, 2006b) porosity calculator using an estimated bulk density of 1.9 tonnes/m^3 for the made ground based on typical made ground density.

Appendix G.1 details the sources of the physiochemical parameter inputs for each CoC, Appendix G.2 provides the RT worksheet outputs, and Appendix G.3 provides the full screening of soil results against the RTs.

Table 6 summarises the calculated Level1 remedial soil targets and the numbers of exceedances against these for soil-phase concentrations of the CoCs.

Table 6. Summary of level 1 RTs and RT exceedances

Determinand	WQS (mg/l)	Level 1 RT (mg/kg)	No. results > LOD	No. RT exceedances	Scheme Area(s)
Anthracene	0.0001	0.11	102	83	1, 2, 3 ,4 5
Benzene	0.010	0.03	5	1	5
Benzo(b)fluoranthene	0.000017	0.08	114	113	1, 2, 3 ,4 5
Naphthalene	0.002	0.06	63	56	1, 2, 3 ,4 5
Toluene	0.074	0.66	8	0	N/A

The results show widespread exceedances of the EQSs across the scheme areas, as would be expected based on the results of total soils testing for PAHs and speciated hydrocarbon bands, summarised as follows:

- most RT exceedances were for anthracene and benzo(b)fluoranthene, representative of the >EC16-EC21 and >EC21-EC35 carbon bands respectively

- around a third of the samples tested (55 of 154) had naphthalene concentrations in excess of the RT, representative of the >EC10-EC12 carbon band
- no RT exceedances were identified for toluene, representative of the >EC7-EC8 carbon band
- only 1 RT exceedance was identified for benzene, representative of the >EDC5-EC7 carbon band, in a sample from WS05-7.

7.2.4 Visual and olfactory evidence of contamination and risks to controlled waters

In addition to the assessment of soil leachate and total soils results above, consideration has been given to visual and olfactory evidence of contamination recorded during GI.

No gross contamination, such as free phase hydrocarbon product in soils was observed during the GI. Hydrocarbon odours were recorded in WS26-4 (Area 3 Reach A) and WS36-4 (Area 4 Reach C). However, only low concentrations of hydrocarbons were detected in a soil sample at the observation depth in WS26-4.

Elevated total petroleum hydrocarbon concentrations were recorded in a soil sample at the observation depth in WS36-4, the majority of which were heavier-end hydrocarbons (typically PAHs). The source of the hydrocarbons is not known, and further delineation was not undertaken during the GI works. An embankment is proposed to be constructed in this location, and if any excavations were proposed to the depth profile of the observation, consideration should be given to the earthworks and subsequent material management of the spoil arising.

7.2.5 Risk evaluation for Areas 1 to 5

Although the results of laboratory testing indicate potential risks to controlled waters, it is considered that these are not unacceptable in the context of the scheme for the following reasons:

- The vast majority of leachate WQS exceedances and elevated organic determinand concentrations in site soils are not linked to a specific source, being dispersed throughout made ground at the site and most likely a result of the presence of isolated ash and clinker fragments. As such the observed concentrations are considered to representative of background concentrations in the wider area given the urban site setting.
- Visual/olfactory evidence of contamination is limited, and where hydrocarbon odours were recorded during GI associated risks are considered to be low, as discussed above in Section 7.2.4.
- The shallow geology at the site (made ground and superficial deposits) largely comprise granular materials, such that the relatively shallow piling proposed as part of the scheme is unlikely to significantly exacerbate any downward migration of contaminants to groundwater.
- Soil leachate analysis tends to overestimate the likely concentrations of contaminants in eluate, such that the assessment of inorganic leachate results represents a conservative approach.
- The theoretical partitioning of organic determinands represents a conservative theoretical assessment of the risk of contaminant leachability.
- Most hydrocarbons detected in total soils testing were in heavier hydrocarbon bandings, the mobility and solubility of which is relatively low. Only one benzene EQS exceedance was predicted from the theoretical partitioning assessment, and BTEX in general was only detected in a small number of samples, with no MTBE identified; these are the particularly mobile and harmful hydrocarbons for the aquatic environment.

7.3 Ground gas

Ground gas monitoring was only undertaken for 5 boreholes installed during the WYG (2012) investigation within Area 1 Reach A and Area 2 Reach C. These data show maximum methane concentrations of 0.1 %, generally low flow rates and generally low carbon dioxide concentrations, but up to 8.4 % in WS103.

With reference to CL:AIRE (2012), the results of the GI across the scheme suggest limited potential for ground gas generation based on made ground depths, material descriptions and *in situ* observations. It is considered that there are no viable sources of significant ground gas at the site, and there is limited hardstanding proposed which could confine gases and exacerbate any migration of ground gases to off-site buildings. As such, ground gases are not considered to present any unacceptable risks.

7.4 Updated conceptual model

Based on the GI data review and GQRA, Table 7 presents an updated conceptual model and potential pollutant linkages.

Table 7. Updated pollutant linkages

Source	Contaminants	Pathway	Receptor	Risk Identified
Made ground resulting from historical land uses, built development and import of materials with unknown provenance to facilitate land raising adjacent to river corridors.	Asbestos, barium, lead and PAHs	Ingestion, inhalation and/or dermal contact	Construction workers	Potential localised risks associated with the reuse and retention of the made ground in the scheme identified – refer to Section 9
		Ingestion, inhalation and/or dermal contact (where hard-standing or overlying clean soils are absent)	Site users (members of the public)	
		Wind-blown migration of contaminants (e.g. asbestos) followed by inhalation	Adjacent land users (e.g. nearby residents)	
	Metals, inorganic compounds (e.g. ammoniacal nitrogen) and organic compounds (e.g. PAHs)	Vertical and lateral migration of leachable contaminants into groundwater and surface waters	River Ribble	No environmental risks identified associated with the reuse and retention the made ground in the scheme.
			River Darwen	
			Secondary A Aquifers (granular superficial deposits)	
			Principal Aquifer (Sherwood sandstone)	
	Ground gases (e.g. carbon dioxide)	Migration and accumulation of explosive or asphyxiating gases	Adjacent land users (e.g. nearby residents)	No environmental risks identified
			Buildings	

8. Preliminary waste classification

8.1.1 Hazwaste

Should it be elected to dispose of excavated site soils to landfill, an indicative hazardous/non-hazardous assessment of the likely waste classification of excavated material was undertaken in accordance with current regulations, as they apply in England (EA, 2015).

The assessment, based on the total soil chemical analysis was undertaken using "HazWasteOnline™", a web-based assessment tool which conforms with the regulations.

The output sheets from the "HazWasteOnline™" web tool are presented in Appendix H.

Assessment of the total soil chemical analysis has characterised the following samples as hazardous, for waste disposal to landfill:

- **16 samples across Areas 1, 2, 3 and 4:** TPH concentrations between 1,050 mg/kg and 7,078 mg/kg, on the basis of hazard statements HP7 (carcinogenic) and HP11 (mutagenic)
- **1 sample Area 1:** WS57-3 at 1.0 mbgl – copper and lead concentrations of 904.6 mg/kg and 2,230 mg/kg respectively, on the basis of HP7 (carcinogenic) for lead and HP14 (ecotoxic) for copper and lead
- **1 sample Area 3:** WS26-2 at 1.2 mbgl – lead concentration of 1,240 mg/kg, on the basis of HP7 (carcinogenic).

8.1.2 Asbestos

As summarised in Section 7.1, asbestos fibres were detected in one sample at 0.864 % (TT05-3, 0.5 mbgl, Area 5 Reach B), while quantification was not undertaken for a further three samples in which asbestos was identified through visual screening.

The material from TT05-3 would likely require disposal as hazardous waste given the concentration of asbestos detected exceeds the hazardous waste threshold of 0.1 %. The concentration of asbestos fibres within the remaining three samples is unknown and therefore quantification would be required to determine a suitable disposal route.

Should disposal be pursued of materials within the vicinity of these asbestos detections, additional sampling within the areas of excavation would help to delineate the areas affected by asbestos and determine the volumes to be disposed of at hazardous landfill as necessary.

This is an indicative preliminary assessment and as such additional testing and assessment may be required by the receiving landfill. Furthermore, it is possible for asbestos-containing waste soils to be disposed of in a non-hazardous waste landfill, provided it is landfilled within a separate, self-contained cell; potential landfills with this facility would need to be consulted.

8.1.3 Summary

Preliminary assessment indicates that made ground from the majority of the site should be suitable for disposal as non-hazardous waste. Furthermore, in accordance with regulations, any uncontaminated natural ground (excluding topsoil and any peat that might be encountered during excavations) should be suitable for disposal to a non-hazardous or inert landfill.

Prior to the disposal of any soils to landfill, additional waste classification analysis including Waste Acceptance Criteria (WAC) testing may be required by the receiving landfill.

9. Conclusions and recommendations

A review of available GI data has been undertaken to provide an assessment of potential risks from land contamination within the scheme areas. Made ground was found to be widespread across the scheme but visual and olfactory evidence of contamination was limited to hydrocarbon odours in two locations and asbestos fibres in one location.

9.1 Human health

Elevated contaminant concentrations in the made ground were detected, primarily PAHs but also barium and lead, with asbestos fibres identified in several locations. Interpolations of the extents of the made ground associated with the GAC exceedances have not been undertaken. However, contaminants appear to be diffuse throughout the made ground and are not associated with a point source.

No unacceptable risks to future site users or controlled waters have been identified, provided that the following actions are adhered to:

- **Area 1 Reach A:** Soils within Broadgate Gardens are left *in situ*, due to elevated PAH concentrations.
- **Area 2 Reach A:** soils adjacent to Penwortham Methodist Church are retained beneath any imported fill for the proposed raising of ground level, due to elevated PAH concentrations
- **Area 4 and 5:** with respect to asbestos, isolated detections were recorded which are considered to present potential risks to future site users or adjacent land users, if the materials are exposed, excavated and/or reused.

With respect to suitability for reuse, any soils in the vicinity of where human health GAC exceedances or asbestos fibres have been recorded (see Figure 2), which are excavated and intended for reuse on site, should only be reused beneath hard-standing or a minimum of 600 mm of clean soils. The extents of contamination should be verified during the works.

9.2 Construction works

Beyond normal health and safety measures, potential acute risks to construction workers and adjacent land users from ACMs in limited parts of Areas 4 and 5 have been identified; these should be managed via pre-construction planning and the implementation of an appropriate asbestos management plan to mitigate any potential risks. Further guidance can be obtained in CL:AIRE (2016).

This should be considered in pre-construction planning and risk assessment and method statements for any earthworks, and appropriate safety measures taken on site to mitigate risks. Potential risks to adjacent land users from airborne dispersion and subsequent inhalation of asbestos fibres during construction should also be factored into this planning, with measures such as dust suppression implemented as required.

9.3 Controlled waters

Concentrations of inorganic contaminants in soil leachate and predicted theoretical pore water organic contaminant concentrations are elevated across the scheme, associated with the widespread presence of ash and clinker fragments. However, given the evaluation of the risks presented above it is considered that the likely limited reuse of made ground in the vicinity of excavations would not alter the existing risks, given the background soil chemical quality.

Notwithstanding the above, if significant excavation and reuse or relocation of made ground is required, i.e. movement of soils between reaches, then a site-specific assessment of the risk to controlled waters from the material would be required. Interpolations of the extents of the made ground associated with the exceedances have not been undertaken.

Elevated total petroleum hydrocarbon concentrations were recorded in a soil sample at the observation depth in WS36-4, the majority were heavier-end hydrocarbons (typically PAHs). The source of the hydrocarbons is not known, and further delineation was not undertaken during the GI works. An embankment is proposed to be constructed in this location, and if any excavations were proposed to the depth profile of the observation, consideration should be given to the earthworks and subsequent material management of the spoil arising.

9.4 Materials and environmental management plans

If excavated materials are to be reused, a Materials Management Plan (MMP) should be prepared in accordance with *The Definition of Waste: Development Industry Code of Practice* (CL:AIRE, 2011) to mitigate any potential risks to human health and the environment that may arise due to on-site reuse, by ensuring suitability prior to reuse.

Preparation of a site waste management plan (SWMP) should be considered if excavated materials are to be disposed off-site.

Other risks can be managed by the contractor, who should operate in accordance with pollution prevention guidance (DEFRA & Environment Agency, 2019) and develop a Construction Environment Management Plan (CEMP) and/or Construction Code of Practice (CCoP).

9.5 Piling risk assessment

The shallow geology at the site (made ground and superficial deposits) largely comprises granular materials, such that the relatively shallow piling proposed as part of the scheme is unlikely to significantly exacerbate any downward migration of contaminants to groundwater. However, a formal piling risk assessment may need to be completed with regards to other risks associated with piling.

9.6 Contamination watching brief

There are inherent uncertainties associated with environmental sampling of heterogeneous subsurface materials, particularly in urban environments with mixed histories of land use. As such, the potential for encountering unidentified/unforeseen contamination remains present during the proposed works.

It is therefore recommended that a watching brief is maintained for visual and olfactory evidence of contamination during groundworks at the site. Any potentially contaminated materials should be segregated and subjected to sampling and appropriate analysis. Assessment of the chemical testing results should be undertaken in order to determine risks to human health or the environment and documented.

9.7 Waste characterisation

A preliminary waste classification has been undertaken should disposal be required, which indicates that some materials would likely require disposal at hazardous waste landfills, but additional testing and assessment may be required by the receiving landfill(s).

10. Limitations

The findings of this report were developed in a manner consistent with a level of care and skill normally exercised by members of the environmental science and engineering profession currently practising under similar conditions.

A number of the findings and conclusions presented in this report are based on information provided by third parties and, which Jacobs has relied on in good faith. Jacobs accepts no responsibility for any deficiency, misstatements, or inaccuracy contained in this report as a result of errors, omissions or misstatements of said third parties or from information obtained from these.

The potential remains for the presence of unknown, unidentified, or unforeseen surface and sub-surface contamination beyond those areas investigated. Any additional evidence of such potential site contamination would require appropriate surface and subsurface exploration and testing.

This report is intended to support the proposed Preston FRMS and should not be used for other purposes. The report is currently only complete for Areas 1 and 2 to support the planning application, and will need to be reviewed and updated as required for Areas 3, 4 and 5 prior to submission for planning approval of these works. The conclusions of this report should also be re-assessed should there be any material changes to the design for any areas.

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Figures

Appendix A. General arrangement drawings

A.1 General arrangements for Area 1

A.2 General arrangements for Area 2

A.3 General arrangements for Area 3

A.4 General arrangements for Area 4

A.5 General arrangements for Area 5

Appendix B. Environmental masterplan for Areas 1 and 2

Appendix C. Desk studies

C.1 Arup 2013 Areas 1 and 2

C.2 Arup WCML to M6 – Areas 1, 2 and 3

C.3 CH2M desk study – all areas

Appendix D. Factual reports

D.1 White Young Green (2012)

D.2 AEG (2019)

D.3 IFA (2020)

Appendix E. Geological cross-sections

Appendix F. Geoenvironmental screening of results

Appendix G. Remedial targets parameters and screening

G.1 Physiochemical parameters

G.2 Remedial target worksheet outputs

G.3 Screening of soil results against remedial targets

Appendix H. Hazwaste report