


Midland Metro Phase 2 Eastside

Geotechnical Desk Study Report
MMD-300207-HS02-DOC-002 Rev B

November 2014

Centro

Mott MacDonald

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Centro House
16 Summer Lane
Birmingham
B19 3SD

Mott MacDonald, 35 Newhall Street, Birmingham, B3 3PU, United Kingdom
T +44 (0)121 234 1500 **F** +44 (0)121 200 3295 **W** www.mottmac.com

Issue and revision record

Revision	Date	Originator	Checker	Approver	Co-ordination	Standard
A	January 2013	AJ Preston	HT Brocklebank	H Brocklebank	C Searson	
B	November 2014	J Weston	AJ Preston	HT Brocklebank	C Searson	

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Executive Summary

Objectives

The purpose of this revised Desk Study Report is assessment of geotechnical and geoenvironmental constraints to aid Optioneering between three proposed routes linking the Midland Metro Phase 1, Birmingham City Centre Extension to a proposed Park and Ride site in Bordesley.

Route Description

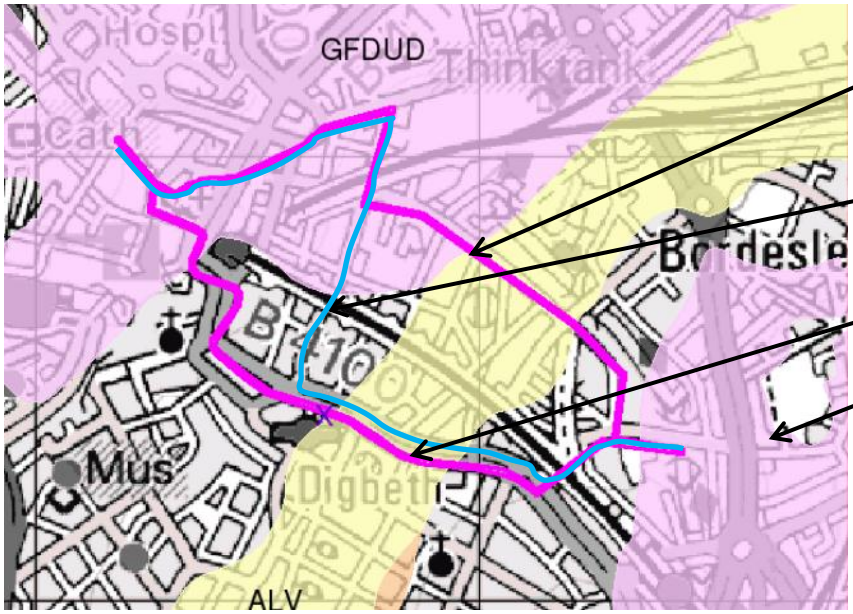
- Route Option A: is based on the initial optioneering phase; with the route serving the proposed High Speed 2 station site. It runs from Bull Street to Moor Street Queensway via New Meeting Street, which requires a building to be demolished, before continuing towards the former Curzon Street Station and then turning south onto New Canal Street. The route then turns eastwards along Fazeley Street continuing onto Liverpool Street before merging onto Adderley Street where the route finishes at the Grand Union Canal crossing.
- Route Option B: combines the western section of Route Option A serving the proposed High Speed 2 station site, and the eastern section of Route Option C by linking along New Canal Street and Meriden Street.
- Route Option C: is an alternative route running from Bull Street to High Street and then joining onto Moor Street Queensway via Carrs Lane. The route follows Moor Street Queensway into Digbeth continuing along the B4100 onto High Street Deritend. The route turns northwards at Adderley Street before finishing at the crossing of the Grand Union Canal.

Geology and Ground Conditions

The published geological mapping indicates that a significant thickness (>2.5m) of Made Ground is present underlying the western end of the site associated with the city centre development. However Made Ground is likely to underlie the majority of the route due to historical land use and the presence of infilled ground along the Route Options. Made Ground is highly variable in composition, has the potential to be poorly compacted, and may be prone to excessive consolidation and therefore may be an important impact on the stiffness of track slab design and for structural foundations.

All three route options have similar geology with Glaciofluvial Deposits indicated to be present in high elevation areas at the western end of the site and at the extreme eastern end of the scheme. A tract of Alluvium is present towards the middle of the Route Options formed by the River Rea. The indicated Superficial deposits underlying the

Route Options are presented below.



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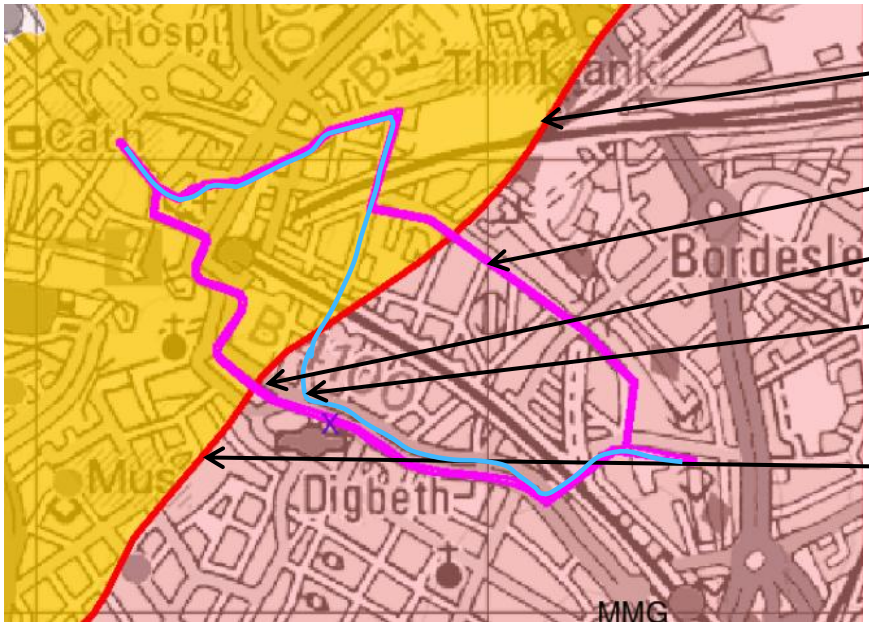
Key

Hatch	Code	Deposit
	GFDUD & GFDMP	Glaciofluvial Deposits
	ALV	Alluvium
	RTD1	River Terrace Deposits

Glaciofluvial deposits are typically sand and gravel, with locally present lenses of silt, clay or organic material. Unsupported excavations within Glaciofluvial deposits are likely to be unstable, particularly if there is shallow groundwater present. Glaciofluvial deposits generally represent good founding conditions, however cohesive material present may be soft, compressible and unsuitable load bearing strata with potential for large displacements.

Alluvium deposits are typically highly compressible normally consolidated deposits dominated by soft clay with localised deposits of peat which are generally unsuitable as founding material due to the potential for large displacements under loading, which is critical for track slab design. Piling or ground improvement may be required.



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Key

Hatch	Code	Deposit
	BMS	Bromsgrove Sandstone Formation
	MMG	Mercia Mudstone Group
	-	Fault

The underlying solid geology of all three Route Options is split by the Birmingham Fault into the Bromsgrove Sandstone Formation to the west of the fault, and the Mercia Mudstone Group to the east of the fault, as shown above.

The Bromsgrove Sandstone Formation is formed of sandstones, commonly pebbly or conglomeratic at the bases of beds, interbedded with red and brown siltstones and mudstones. The Bromsgrove Sandstone may also be encountered as highly weathered material to a residual soil state. This weathering may vary with depth resulting in interbedded deposits of sand and sandstone, with subordinate bands of mudstone and clay. Subordinate mudstone and clay bands may degrade significantly if left exposed to wet weather with the potential for compressibility and differential settlement in cohesive layers.

The Mercia Mudstone Group is formed mudstones and subordinate siltstones with thick halite-bearing units in some basinal areas. Thin beds of gypsum / anhydrite are widespread. Sandstone beds are also present. The Mercia Mudstone Group deposits are also typically encountered as highly weathered material in near surface deposits to a

residual soil state. This weathering may vary with depth resulting in interbedded mudstone and clay. Mudstone may degrade significantly if left exposed to wet conditions, leading to compressibility and differential settlement of cohesive layers.

Constraints

This report highlights ground constraints relating to the different route alignments and where possible highlights differences between the three Route Options. A comparison of the three routes highlighting key differences identified during the assessment of the ground conditions and site setting are summarised in tabular format on the following page:

Measure	Route Option A	Route Option B	Route Option C
Route length	1850m	2250m	1820m
Length of route passing through industrial areas (increased potential for contamination)	1020m	840m	370m
Length of route underlain by Made Ground in excess of 2.5m thick (as shown on Envirocheck mapping) Thick highly variable Made Ground may result in poor foundation performance due to the potential for large track displacements unless ground support improved	420m	420m	660m
Length of the route underlain by Glaciofluvial Deposits which may result in difficult conditions for unsupported excavations unless support provided	1230m	1150m	510m
Length of the route underlain by Alluvium which may be soft, compressible and unsuitable for the founding of structures, unless mitigated in the foundation design	260m	320m	320m
Length of the route falling within the Environment Agency 1:100 year flood event	240m	400m	400m
Building demolition required	Yes (none of which have a statutory listing)	Yes (none of which have a statutory listing)	No
Proximity to tunnels	Close to the Moor Street to Snow Hill tunnel on Bull Street	Close to the Moor Street to Snow Hill tunnel on Bull Street	Crosses the New Street tunnel outside Moor Street Station. Above or close to Moor Street to Snow Hill Station on Carrs Lane, High Street and Bull Street.
Bridges crossing the route which may pose constraints on the route development	Railway over bridge Canal under bridge (x2) River under bridge	Railway over bridge (x4) Canal under bridge River under bridge	Railway over bridge (x2) Canal under bridge River under bridge
Other	Elan Aqueduct may underlie a section of the route adjacent to former Curzon Street Station	Infilled channels adjacent to the River Rea Elan Aqueduct may underlie section of the route along New Canal Street and Meriden Street	Infilled moat Infilled channels adjacent to the River Rea

There are a number of constraints highlighted within this report that affect each of the Route Options, each of which will have a cost implication in order to mitigate the impact upon the proposed development. The primary constraints for each Route Option can be considered as follows:

Route Option A

- Indicated significant thickness of Made Ground underlying the western end of the site with variable composition and potential for excessive settlement;
- Glaciofluvial deposits indicated to be present underlying the western end of the route and at the extreme eastern end of the route;
- Indicated presence of Alluvium deposits associated with the River Rea underlying the middle section of the route on Fazeley Street, with the potential for large displacements under loading;
- The Moor Street to Snow Hill tunnel is indicated to underlie Bull Street, and the potential presence of the Elan Aqueduct along New Canal Street. Such structures may affect the loading requirements of the scheme. The positioning and details of the concerned structures will need to be investigated;
- Potential for buried structures at site of former Banbury Street and Bartholomew Street residential buildings, and the potential for buried concrete slabs or localised voids within the highway as encountered during previous ground investigation works within the city centre;
- The presence of a building to be demolished to make way for the tramline at the junction of Dale End and High Street;
- A railway over bridge crossing the route on New Canal Street;
- Crossing a canal underbridge on Fazeley Street, and at the end of the route chainage on Adderley Street;
- Crossing the River Rea on Fazeley Street;

Route Option B

- The Elan Aqueduct was identified on historical OS mapping to underlie Meriden Street and New Canal Street with approximately 800m of the route affected. The existence and positioning of the structure will need to be investigated through obtaining utility plans from Severn Trent Water. If present, the structure is likely to be of Major Significance due to its importance and potential susceptibility to loading;
- Potential for buried structures at site of former Banbury Street and Bartholomew Street residential buildings, and the potential for buried concrete slabs or localised

voids within the highway as encountered during previous ground investigation works within the city centre;
- Basement structures were observed at the southern end of Meriden Street underlying the existing footway. The extent of these structures will need to be confirmed for design purposes, and the presence of any further basement structures affecting the Route Options will need to be investigated;
- The potential for poorly infilled water channels associated with historical industrial development on the banks of the River Rea and poor backfill behind the existing river bank walls, and infilled canal channels adjacent to New Canal Street. Highly variable, poorly consolidated material may be present that has the potential for significant compressibility;
- The presence of a building to be demolished to make way for the tramline at the junction of Dale End and High Street;
- The Moor Street to Snow Hill tunnel is indicated to underlie Bull Street, and Route Option B may also be affected by the potential presence of tunnels adjacent to High Street Deritend and Digbeth;
- Four railway over bridges cross the route, with two structures on New Canal Street and two on Adderley Street;
- The route crosses the River Rea at High Street Deritend, and the Birmingham Canal is present at the end of the route chainage on Adderley Street;

Route Option C
- Indicated significant thickness of Made Ground underlying the western end of the site with variable composition and potential for excessive settlement;
- Glaciofluvial deposits indicated to be present underlying the western end of the route and at the extreme eastern end of the route;
- Alluvium deposits associated with the River Rea crossing at High Street Deritend, with the potential for large displacements under loading;
- The potential for poorly infillled water channels associated with historical industrial development on the banks of the River Rea and poor backfill behind the existing river bank walls, and the potential presence of a poorly infilled moat in the vicinity of Moat Lane. Highly variable, poorly consolidated material may be present that has the potential for significant compressibility;
- The route may cross the Elan Aqueduct at the junction of Meriden Street and the B4100;
- The Moor Street to Snow Hill tunnel crosses the route at Bull Street, High Street and Carrs Lane. The New Street tunnel also crosses the route at Moor Street Queensway. Potential tunnels are indicated to be present approximately 100m south of the route at High Street Deritend and Digbeth as highlighted by tunnel related ground

investigations undertaken in the 1960s. The existence of potential tunnels will need to be investigated further;
- The potential for buried concrete slabs or localised voids within the highway as encountered during previous ground investigation works within the city centre;
- Two railway over bridges cross the route on Adderley Street;
- The route crosses the River Rea at High Street Deritend, and the Birmingham Canal is present at the end of the route chainage on Adderley Street;

Potential Contamination

There have been a number of different industries along the route of each Route Option that may provide a source of potential contamination affecting the Route Options.

The Bromsgrove Sandstone Formation underlying the western section of the scheme is designated as a Principal Aquifer by the Environment Agency indicating that the deposit provides a high level of water storage and can provide a major pathway for contaminants.

The underlying Superficial Deposits are designated by the Environment Agency as Secondary A Aquifers indicating that they are capable of supporting water supplies at a local level and potential pathways for contaminants. The Mercia Mudstone Group underlying the eastern section of the scheme is designated as a Secondary B Aquifer indicating that the deposit contains predominantly lower permeability layers which may store and yield limited amounts of groundwater and potential pathways for contaminants.

The primary contamination sources affecting the Route Options are historical works along the route options such as Metal Works including foundries, fabrication, and metal finishing within 100m of the Route Options; and a historical Gas Works on Adderley Street that was sited immediately adjacent to the proposed routes. The Gas Works was identified on historical OS mapping between 1890 and 1952, and comprised at least five large tank structures identifiable on mapping. The potential contamination from these industries will need to be targeted during recommended ground investigation.

Ground Investigation

Upon confirmation of the development Route Option it is strongly recommended that a targeted ground investigation for the specific route option is undertaken in order to aid design and aid mitigation and understanding of the highlighted constraints. The

investigation should comprise of both an non-intrusive investigation and an intrusive ground investigation. The non-intrusive investigation should include:

- GPR survey of the route corridor to identify the presence of buried structures and below ground voids,
- GPR and utility survey of the route corridor to identify the presence of buried services,
- GPR survey of basement walls and retaining walls in order to determine geometry, structural capacity and suitability for continued use as part of the permanent works,
- GPR survey of building walls at any OLE building fixing locations in order to accurately determine geometry and structural capacity for the resisting of applied OLE loading, and,
- Visual condition survey of structures and existing buildings (internal and external), and to check for basements under existing footways.

The scope of intrusive ground investigation should be confirmed after review of non-intrusive GPR survey works is undertaken to aid effective targeting of the ground investigation. The works are likely to include, but may not be limited to the following:

- Deep dynamic sampler boreholes with rotary follow on, and windowless sampler boreholes to confirm the ground model for the site, for in-situ Standard Penetration Testing and for the collection of soil and groundwater samples for laboratory testing,
- Inspection pits for identification of structure foundations,
- In-situ stiffness testing in the highway to determine stiffness characteristics of subformation layers (dynamic probing, static plate load testing, dynamic plate load testing etc.),
- Concrete coring through concrete obstructions and structures,
- Geotechnical laboratory testing to determine geotechnical parameters,
- Chemical testing to determine concrete design requirements, and,
- Contamination testing in order to determine risk to human health and the environment and to determine waste acceptance criteria.

Other requirements

- Liaison with Network Rail for working in the vicinity of tunnel structures and retaining walls,
- Liaison with Birmingham City Council (and their highway maintenance contractor) for traffic management arrangements,
- Liaison with High Speed 2 station developers,
- Further investigation of possible tunnels in the vicinity of Digbeth and High Street Deritend.
- Collation and review of as-build drawings for structures in the vicinity of the site, and,

- Collation and review of utility plans in order to identify and confirms features such as the Elan Aqueduct.

1 Introduction

1.1 Background

In July of 2012 Mott MacDonald were appointed by Centro to develop Route Options connecting the Midland Metro Birmingham City Centre Extension (BCCE) to the proposed High Speed Rail link station on New Canal Street. Subsequently the route was extended to Bordesley (approx. 1.5km southeast of Birmingham city centre), necessitating an update of this Desk Study Report.

This report compares three options identified for the extended route, and undertakes a high level appraisal of constraints which may impact on tramway construction and ongoing infrastructure performance.

1.2 Scope of Work

This report highlights ground constraints for the three Route Options in order to aid with Route Optioneering, and the Department for Transport WebTAG processes. Following on from the optioneering process a single Route Option will be taken forward to detailed appraisal and submission of a Transport and Works Act order.

1.3 Report Objectives

The objectives of this Desk Study are to:

- Establish geological and hydrogeological conditions along the proposed routes using existing available information;
- Review existing ground investigation data to establish the likely ground conditions along the proposed routes;
- Construct a qualitative contaminated land risk assessment from onsite and offsite sources;
- Identify environmental, ground and site constraints; and to,
- Provide recommendations with regard to the requirements of Ground Investigation works required to progress the project.

In addressing the above objectives this report will highlight particular advantages and disadvantages of the proposed routes being considered and feed them into the optioneering process.

1.4 Sources of Information

Information reported within this document has primarily been gathered from the following sources:

- Online geological mapping[i];
- Published BGS literature and mapping[ii iii];
- Envirocheck Reports[iv v] for the site procured by Mott MacDonald;
- Online historical borehole scans[vi];
- Environment agency online resources[vii];
- The Magic.gov website[viii];
- The Archaeology Data Service (ADS) website[ix];
- Observations made during a site walkover of the initial two proposed routes on 14th February 2014, and the third option on 20th August 2014 (walkover notes and photographs attached to this document as Appendix B);

- The Midland Metro Phase 1, Birmingham City Centre Extension (BCCE) factual ground investigation information[x];
- The existing Desk Study Report for the BCCE to High Speed 2 (HS2) link[xi].

A full list of references used during the writing of this report is presented as Appendix G.

2 Site Location and Description

The site is located in, and to the southeast of Birmingham city centre. The Eastside area of Birmingham is earmarked for redevelopment/regeneration and the provision of the Midland Metro Phase 2 link forms a key part of the regeneration plans. Three number Route Options are being considered at the time of writing this report; a site location plan and route plans are presented in Appendix A of this document.

Throughout this document the Midland Metro Phase 2 tramway is referred to as "the site", indicating non route specific text, or as Route Option A, Route Option B, or Route Option C for alignment option specific text. An Envirocheck report purchased specifically for production of this document covers each proposed Route Option as detailed below.

2.1 Option Details

Route Option A is based on an initial optioneering study and serves the proposed location of the High Speed 2 station. Route Option B combines the western section of Route Option A and the eastern section of Route Option C thus limiting works around Moor Street Station, but providing a link between the proposed HS2 station and Birmingham Coach Station via New Canal Street and Meriden Street. Route Option C is an alternative route proposed from Bull Street via Moor Street Queensway which avoids the demolition of any buildings. All three Route Options run predominantly on existing highway routes. The routes and any resulting demolition of existing buildings being limited to discrete areas as highlighted in tabular format in sections 2.1.1, 2.1.2 and 2.1.2.

2.1.1 Route Option A

Approximate route length = 1850m

Chainage	Route Section	Notes	Photo ref.
10150m	Starts at the Bull Street Corporation Street junction	* **	1
10150m to 10280m	Down lower Bull Street	* **	1 to 4
10280m to 10450m	Down New Meeting Street (upper section of which is footpath only) and Albert Street	Demolition of a single building required **	5 & 63 to 65
10450m to 10820m	Across Moor Street Queensway and along Albert Street (part of which is pedestrianised) and parkland areas adjacent to Park Street and the former Curzon Street station	**	57 to 62
10820m to 10980m	New Canal Street, past the disused Curzon Street Station building	**	52 to 56
10980m to 11530m	Along Fazeley Street	Building demolition required in areas of proposed redevelopment	42 to 51
11530m to 11860m	Along Liverpool Street	*	38 to 41
11860m to 12000m	Along Adderley Street	**	35 & 37
12000m	Route ends at the Adderley Street crossing of the Warwick and Birmingham Canal	* **	35

*Partial or fully common route sections with Route Option B
**Partial or fully common route sections with Route Option C

2.1.2 Route Option B

Approximate route length = 2230m

Chainage	Route Section	Notes	Photo ref.
9770m	Starts at the Bull Street Corporation Street junction	* **	1
9790 to 9900m	Down lower Bull Street	* **	1 to 4
9900 to 10050m	Down New Meeting Street (upper section of which is footpath only) and Albert Street	*	5 & 63 to 65
10050 to 10400m	Across Moor Street Queensway and along Albert Street (part of which is pedestrianised) and parkland areas adjacent to Park Street and the former Curzon Street station	*	57 to 62
10400 to 10500m	Turn onto New Canal Street, past the disused Curzon Street Station building	*	53 to 56
10500 to 11050m	Continue along New Canal Street underneath railway bridges for the New St line and Moor St to Snow Hill line, onto Meriden Street		52 & 66 to 76
11050 to 11100m	Turn onto High Street Deritend from Meriden Street	**	77 to 79
11100m to 11660m	High Street Deritend	**	19 to 29
11660m to 12000m	Adderley Street	* **	30 to 37
12000m	Route ends at the Adderley Street crossing of the Warwick and Birmingham Canal	* **	35

*Partial or fully common route sections with Route Option A
**Partial or fully common route sections with Route Option C

2.1.3 Route Option C

Approximate route length = 1820m

Chainage	Route Section	Notes	Photo ref.
10180m	Starts at the Bull Street Corporation Street junction	* **	1
10180m to 10310m	Lower Bull Street	* **	1 to 4
10310m to 10350m	High Street		6 & 7
10350m to 10460m	Carrs Lane		8 & 9
10460m to 10560m	Along Moor Street Queensway in a southerly direction		10 to 14
10560m to 10680m	Moor Street		15 & 16
10680m to 10820m	Park Street		17 & 18
10820m to	Digbeth	**	19 to 29

Chainage	Route Section	Notes	Photo ref.
11000m			
11100m to 11630m	High Street Deritend	**	
11630m to 12000m	Adderley Street	* **	30 to 35
12000m	Route ends at the Adderley Street crossing of the Warwick and Birmingham Canal	* **	35

* Partial or fully common route sections with Route Option A
**Partial or fully common route sections with Route Option B

2.2 Land Use

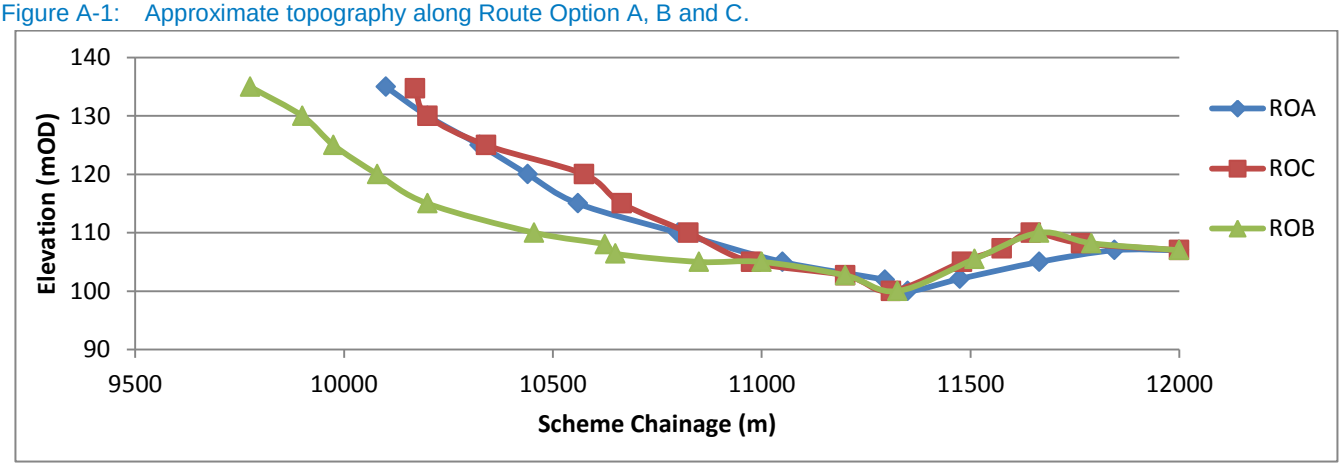
All three routes start in the city centre, in areas dominated by retail development. Route Option A crosses Moor Street Queensway into areas dominated by parkland and landscaped areas associated with the Millennium Point development (planned location of the HS2 station). On passing under the existing railway bridge at the junction of New Canal Street and Fazeley Street, Route Option A passes through existing narrow urban streets in areas of the city dominated by light industry. Route Option C follows existing major highways along Moor Street Queensway past Moor Street Station and the Bullring shopping centre, and then eastwards along the B4100. At the junction of High Street Deritend and Adderley Street Route Option C passes from the major highway route into the light industry dominated area. Route Option B follows Route Option A to the junction of New Canal Street with Fazeley Street. From this point Route Option B continues along New Canal Street, passing under a second railway bridge before merging with Route Option C at the junction of Meriden Street and the B4100. Route Option B then follows the route of option C up to the eastern end of the site on Adderley Street.

Photographs taken during the Mott MacDonald walkover survey of the Route Options are presented within Appendix B of this document.

2.3 Topography

Generally the topography of the site falls rapidly from the western end of the route (approx. 133mAOD) down to approximately 105mAOD before levelling off across the flood plain of the River Rea. At the extreme eastern end of the site ground level rises up gently to 107mAOD on Route Option A and 108.2mAOD on Route Option C and B respectively. The lowest point on each of the three Route Options is defined by the location of the River Rea and is at 101.8mAOD for Route Option A and at 100.9mAOD for Route Options B and B. Approximate topography of the three Route Options is presented below:

Figure A-1: Approximate topography along Route Option A, B and C.



Source: Envirocheck spot height data

2.4 Geology

Geology along the three Route Options is discussed below, whilst Envirocheck geological mapping for the site is reproduced within Appendix C.1 of this document.

There are minor discrepancies between Envirocheck 1:10,000 scale geological mapping and British Geological Survey (BGS) 1:50,000 scale geological mapping in this area of Birmingham. It is assumed that these discrepancies are due to relative mapping scales. For consistency this report is based upon the distribution of geological formations on the more detailed Envirocheck geological mapping.

2.4.1 Site setting

Much of the West Midlands is shown on BGS geological mapping to be underlain by Quaternary age deposits of Glacial Till and Glaciofluvial Deposits. Subsequently these deposits have been eroded by streams and rivers with Glacial Deposits remaining on higher ground and within deeply eroded and buried

valley features. Recent deposition of river detrital deposits (River Terrace Deposits and Alluvium) has occurred around water courses in valley bases.

In the eastside area of Birmingham, Glaciofluvial Deposits remain on higher ground to the northwest and southeast of the site. The Glaciofluvial deposits south east of the site lie in a buried valley feature that follows a north south orientation. Between these areas fluvial action of the River Rea has resulted in erosion of the Glaciofluvial Deposits, this zone approximately coincides with the area that is affected by a 1:1,000 year flood event. The location of the River Rea defines the position of minimum elevation along each route alignment, around which localised river detrital deposits of Alluvium are present.

2.4.2 Summary of geological formations

Table 2-1: Geological formations present on site

Strata	Age (Period)	Age (years)	Depositional Environment	Typical descriptions
Made Ground	Quaternary	Recent	By man	Highly variable disturbed and deposits, often poorly consolidated and including manmade fragments
Alluvium	Quaternary	up to 2 million years ago	Rivers depositing mainly sand and gravel detrital material in channels to form river terrace deposits, with fine silt and clay from overbank floods forming floodplain alluvium, and some bogs depositing peat; includes estuarine and coastal plain deposits mapped as alluvium.	Normally consolidated, soft to firm compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present.
Glaciofluvial Deposits	Quaternary: (Devensian to Mid Pleistocene)	up to 2 million years ago	Ice Age glaciers scouring the landscape and depositing moraines of till with outwash sand and gravel deposits from seasonal and post glacial meltwaters.	Sand and gravel, locally with lenses of silt, clay or organic material; of glaciofluvial origin
Mercia Mudstone	Triassic: (Anisian to Rhaetian)	200 to 251 million years ago	Hot dry environments where potential evaporation was greater than precipitation; often characterised by dunes, loess and evaporites	Dominantly red, less commonly green-grey, mudstones and subordinate siltstones with thick halite-bearing units in some basinal areas. Weathering effects give rise to the presence of clay layers and variation in engineering properties. Thin beds of gypsum/anhydrite widespread; sandstones are also present.
Bromsgrove Sandstone	Triassic: (Anisian)	237 to 251 million years ago	Rivers depositing mainly sand and gravel detrital material in channels to form river terrace deposits, with fine silt and clay from overbank floods forming floodplain alluvium, and some bogs depositing peat; includes estuarine and coastal plain deposits mapped as alluvium.	Sandstones, red, brown and grey, commonly pebbly or conglomeratic at the bases of beds, interbedded with red and brown siltstones and mudstones.

Source: BGS Geology of Britain viewer and lexicon

Further details of the geological formations present on site are presented below.

2.4.3 Made Ground

Geological mapping procured as part of the Envirocheck reports for the site indicates Made Ground to be present between the eastern end of the site and Moor Street Queensway or Digbeth, corresponding to Ch.10560m on Route Option A, and Ch.10180m on Route Option B, Ch.10820m on Route Option C. Published geological mapping only highlights the presence of Made Ground when its thickness is in excess of 2.5m and therefore it should be assumed that Made Ground is more widespread than indicated by the geological mapping.

Made Ground is highly variable in composition, has the potential to be poorly compacted, and may be prone to excessive consolidation or significant differential settlements under loading. The presence of thick Made Ground may pose constraints on future development or necessitate development of mitigation measures to allow development to commence.

2.4.4 Superficial Geology

Route Option A

Glaciofluvial Deposits are mapped as being present along Route Option A in high elevation areas to the west of Ch.11260m (between Barnfield Street and Pickford Street), and to the east of Ch.11890m (east of the Liverpool Street/ Adderley Street junction). Between approximately Ch.11260 and Ch11890 the River Rea valley dissects the main drift covered terrain, resulting in local absence of superficial deposits; this area approximately coincides with the 1:1,000 year floodplain. Between approximate Ch.11260m and Ch.11540m (Fazeley Street/ Great Barr Street junction) river detrital deposits (Alluvium) associated with the River Rea are shown to be present.

Route Option B

Glaciofluvial Deposits are mapped as being present along Route Option B in high elevation areas to the north and north-west of Ch.10820m (south of the Meriden Street junction with Bordesley Street) and to the east of Ch.11890m (east of the junction of Adderley Street with Liverpool Street). Between Ch.11160m (east of the junction of High Street Deritend with Oxford Street) and Ch.11480m (the junction of High Street Deritend with Gibb Street) alluvial deposits are shown to be present in the River Rea valley base, whilst on the flanks of the river valley no superficial deposits are mapped.

Route Option C

Glaciofluvial Deposits are mapped as being present along Route Option C in high elevation areas to the west of Ch.10560m (Moor Street Station) and to the east of Ch.11890m (east of the junction of Adderley Street with Liverpool Street). Between Ch.11160m (east of the junction of High Street Deritend with Oxford Street) and Ch.11480m (the junction of High Street Deritend with Gibb Street) alluvial deposits are shown to be present in the River Rea valley base, whilst on the flanks of the river valley no superficial deposits are mapped.

At or close to the extreme eastern end of the route BGS mapping highlights the presence of a buried sediment filled paleovalley. The BGS memoir for Birmingham identifies this valley structure to be the Spring Vale paleovalley, and that at its centre Glaciofluvial Deposits have been proven to depths of 29mBGL (80mAOD).

Typically Glaciofluvial Deposits are encountered as SAND and GRAVEL in a clay matrix. In previous Midland Metro related ground investigations in Birmingham city centre Glaciofluvial Deposits have generally been identified by the presence of quartzite gravel. Alluvial deposits are encountered as clay, silt, sand, gravel and organic deposits, and are often found to have soft consistency with a high degree of compressibility and hence have the potential for excessive settlements under loading.

2.4.5 Solid Geology and Structural Geology

The site lies in the western margins of the Knowle Basin, a rift basin of dominantly Triassic sedimentary rocks. The western margin of the Knowle Basing is marked by the Birmingham Fault which crosses the Route Options at the following locations:

- Route Option A at approximate Ch.11190m, close to the Pickford Street/Fazeley Street junction.
- Route Option B at approximate Ch.10880m, close to the railway crossing on Meriden Street.
- Route Option C at approximate Ch.10930m, close to the Allison Street/Digbeth High Street junction.

This major fault trends northeast to southwest and has a down throw of between 60m and 200m to the southeast.

To the west of the Birmingham Fault the solid geology is from the Triassic Bromsgrove Sandstone Formation which was deposited by rivers in the Anisian period (between 242 and 247.2 million years ago). These deposits were mainly lain down in channels as sand and gravel, with fine silt and clay from overbank foods forming floodplain alluvium.

To the east of the Birmingham Fault the solid geology is from the younger Mercia Mudstone Group which was deposited in continental environments ranging from inland lakes to inland evaporitic sabkhas on low gradient floodplains or from suspension from shallow lakes. The Mercia Mudstone Group dates from the Rhaetian to the early Anisian periods (208 to 245 million years ago).

Solid geology in the vicinity of the site is shown on BGS mapping to dip by approximately 2 degrees in a south westerly direction.

2.5 Ground Conditions

Ground conditions along the three Route Options have been determined based on historical borehole logs downloaded from the BGS website, and factual ground investigation data procured as part of the Midland Metro Phase 1 Birmingham City Centre Extension project. Boreholes reviewed in the production of this report are presented graphically on geological long sections attached to this document as Appendix C.2, whilst a summary and interpretation of these ground conditions is presented below as Table 2-2.

Table 2-2: Reviewed exploratory hole logs

Approximate areas			Made Ground Thickness (m)	Superficial geology			Solid geology			Borehole log references
RO1 (Ch. m)	RO2 (Ch. m)	RO3 (Ch. m)		Depth to Top (mBGL)	Thickness (m)	Typical descriptions	Depth to Top (mBGL)	Thickness (m)	Typical descriptions	
Start to 10780 & 10900 to 11030	Start to 10590	Start to 10400 & 10510 to 10870	2.00 to 5.00	Glaciofluvial Deposits (Devensian)			Bromsgrove Sandstone Formation			BH1008 (Geotechnics 2011) SP08NE2424, 2086 & 79 (BGS)
				2.00 to 5.00	1.2 to 3.35	Medium dense to dense silty sand with quartzite gravel, Sand with pebbles	3.56 to 7.10	>0.44 to >4.27	Very dense very silty fine sand, Medium rock sand, and, Sandstone.	
10780 to 10900 & 11030 to 11190	10590 to 10980	10400 to 10510 & 10870 to 10935	1.52 to 5.49	---			Bromsgrove Sandstone Formation			SP08NE38, 39, 2103 & 719 (BGS)
							1.52 to 5.49	>7.98 to >84.62	Interbedded soft sand very soft sandstone and stiff to hard marl, and, fine rock sand. Gravel and Running Sand recorded in SP08NE39 (logged as drift but more likely to be weathered sandstone).	
11190 to 11210	10980 to 11170	10935 to 11160	3.35	---			Mercia Mudstone Group			SP08NE1751 (BGS)
							3.35	>14.33	Marl	
11210 to 11350	11135 to 11450	11160 to 11475	3.05 to 5.18	Alluvium			Mercia Mudstone Group			SP08NE2408, 1750 & 1895 (BGS)
				3.05 to 5.18	1.52 to 2.44	Dense large pebbly gravel, Firm silty clay with gravel	5.18 to 7.62	16.15 to >43.59	Soft to firm red Marl, and, Moderately hard siltstone.	
NA	11340 to 11560	11475 to 11890	unknown	---			Mercia Mudstone			NA
							unknown			
11350 to end	11560 to end	11890 to end	0.31 to 2.70	Glaciofluvial Deposits (Ipswichian to Cromerian)			Mercia Mudstone Group			SP08NE43, 1896, 1871 & 1872 (BGS)
				0.31 to 2.70	5.94 to 22.3	Clay with pebbles, Coarse sand and gravel, Medium sand with traces of clay, Soft to firm sandy clay and gravel	6.25 to 25.00	>4.35 to >54.71	Stiff clay with bands of moderately hard siltstone and sandstone, and, Hard marl.	

Source: BGS website and BCCE factual report

Other observations and notes:

- During review of borehole scans it was observed that tunnel related ground investigations were undertaken in the 1960s approximately 100m to the south of Route Option B and C, parallel to Digbeth and along High Street Deritend. These boreholes indicate the possible presence of tunnels in the vicinity of the Route Option B and Route Option C alignment.
- A localised deposit of Relict topsoil or Peat was encountered in SP08NE2424, at 1.6mBGL. This deposit is outside of the 1:1,000 year flood zone of the River Rea, therefore any peat present in this location is likely to be associated with the underlying Glaciofluvial Deposits.
- A 1.22m void was encountered at 2.13mBGL in SP08NE1751, approximately 70m south of Route Option B and Route Option C alignment.
- Superficial geology in SP08NE130 and SP08NE42 cannot be differentiated based on strata descriptions.
- Bromsgrove Sandstone Formation was identified below the Mercia Mudstone in SP08NE2408 and SP08NE42 at depths of 23.77mBGL and 50.60mBGL respectively, confirming the overall geological sequence.

Based on the historical borehole logs and the geological long sections (Appendix C.2) it is possible to state that:

- The buried channel located to the eastern end of the site appears to extend significantly further west than suggested on the geological mapping for the site.
- Zones where superficial deposits are absent are significantly smaller than indicated on the geological mapping for the site, particularly along Route Option A.
- Made Ground is likely to be more widespread than shown on BGS mapping.

2.6 Geotechnical Parameters

Geotechnical parameters for the Bromsgrove Sandstone Formation and for Glaciofluvial Deposits have previously been identified in the Ground Investigation Report for the Centenary Square Extension project[xii]; extracts of the relevant sections of the GIR being attached to this document with Appendix D.

Made Ground and Alluvium are likely to be highly variable in composition; therefore it is not considered appropriate to quote published geotechnical parameters for these deposits from other sites.

Mercia Mudstone was not encountered as part of the Centenary Square Extension project; however general geotechnical parameters may be found in the following publications:

- Engineering in Mercia Mudstone (CIRIA)[xiii]
- Clay Materials Used as Fill (The Geological Society)[xiv]

The availability of historical and/or published geotechnical data should not be taken to be an alternative for project specific intrusive works, which should be considered imperative in order to quantify site specific geotechnical risks.

2.7 Groundwater

Groundwater monitoring data has been retrieved from the BGS website for borehole SP08NE2304, approximately 120m to the south of Adderley Street. This data highlights a significant increase of groundwater level between 1970 and 1982, and much slower groundwater level increase between 1982 and 1989. No groundwater level readings are available post 1989.

Figure A-1: Groundwater hydrograph for borehole SP08NE2304 (Upper Trinity Street)

Source: BGS borehole scans

Due to the age of available historical ground investigation data and the well published general trend in Birmingham of rising groundwater level with time, it is considered inappropriate to quote levels of groundwater strikes recorded on historical borehole logs. Additionally, groundwater levels are likely to be influenced by seasonal variations, prevailing weather conditions, and other factors.

2.8 Hydrology

Route Option A crosses the Digbeth Branch Canal [photo 50] between the Fazeley Street junctions with Benacre Drive and Pickford Street at Ch.11120m, and crosses the River Rea [photo 46] close to the junction of Fazeley Street with River Street at Ch.11350m. Route Option B and Route Option C cross the River Rea immediately adjacent to the junction of High Street Deritend (B4100) with Floodgate Street at

Ch.11300m and Ch.11325 respectively. In addition, a crossing of the Birmingham and Warwick canal at Ch.12000m is taken to define the eastern end of the site.

The River Rea flows from south to north through a man-made lined channel, well below road level. Due to the provision of the lined channel it is considered unlikely that erosion is undermining the river bank and adjacent structures.

According to the Envirocheck report and Environment Agency flood mapping approximately 240m length of Route Option A (Ch.11230m to Ch.11510m), 400m length of Route Options B and C (Ch.11080m to Ch.11480m) are within a 1:100 year flood zone of the River Rea.

2.9 Hydrogeology

Solid Geology through the eastern half of the site (Bromsgrove Sandstone Formation) is designated by the Environment Agency as being a Principal Aquifer, whilst solid geology through the western half of the site (Mercia Mudstone Group) is designated as being a Secondary B aquifer. All superficial deposits present on site are designated as being Secondary A aquifers. Aquifer designation definitions are as follows:

- Principal Aquifer: Layers of rock or drift deposits that have high intergranular and/or fracture permeability which usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale;
- Secondary A Aquifer: Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers; and,
- Secondary B Aquifer: Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

Environment Agency mapping records Zone 1 Source Protection Zones immediately adjacent to the western end of the site at the junction of Bull Street and Corporation Street. The closest Zone 3 Source Protection Zone is approximately 200m to the west of this location, immediately to the northwest of St. Phillips Cathedral. The Source Protection Zones in the vicinity of the site are limited to areas underlain by solid geology of the Bromsgrove Sandstone Formation.

A number of groundwater abstraction licences are recorded in the Envirocheck Report for the site, these are predominantly towards the western end of the site in areas underlain by the Bromsgrove Sandstone Formation; all being for industrial/commercial purposes.

2.10 Land Designations

2.10.1 Sensitive Land Uses

There are no relevant ecological or sensitive land use designations in close proximity to the site.

2.10.2 Statutory Land Designations

According to the MAGIC.GOV website the whole of the site is within an Objective 1 Area as defined by the European Regional Development Fund. An Objective 1 Area is a region in which the per capita GDP is below 75 percent of the EU average. In these areas funds are provided by the EU to fund economic development trough regeneration and improved infrastructure provision; and hence such designation may increase the likelihood of area regeneration.

The MAGIC.GOV website additionally identifies several listed (statutory) buildings in the vicinity of the proposed route alignments:

- Route Option A:
  - Church of St Michael, Grade II
  - The Woodman Public House, New Canal Street, Grade II
  - The Former Curzon Street Station building, New Canal Street, Grade I,
  - 106-110 and Canal Warehouse, Fazeley Street, Grade II,
  - 122 Fazeley Street, Grade II, and,
  - Public Conveniences attached to the former viaduct structure on Great Barr Street, Grade II.
- Route Option B:
  - Church of St Michael, New Meeting Street / Moor Street Queensway, Grade II
  - The Woodman Public House, New Canal Street, Grade II,
  - The Former Curzon Street Station building, New Canal Street, Grade I,
  - 85 Digbeth, Grade II,
  - 224-225 High Street Deritend, Grade II,
  - The Old Crown Inn, 188 High Street Deritend, Grade II.
- Route Option C:
  - 35-37 Carrs Lane (Powell's Gun Shop), Grade II,
  - Moor Street Station, Moor Street, Grade II,
  - St Martins Church, Bullring, Grade II*,
  - A former ice factory and cold store, 123-135 Digbeth, Grade II,
  - 85 Digbeth, Grade II,
  - 224-225 High Street Deritend, Grade II,
  - The Custard Factory, Gibb Street, and,
  - The Old Crown Inn, 188 High Street Deritend, Grade II.

Further assessment of listed buildings (statutory and local listings) will be undertaken at a later stage as part of the WebTAG process.

None of the listing buildings reported above are planned to be demolished as part of the Metro Works.

2.11 UXO Risk

The Zetica Ltd. Unexploded Bomb Risk Map for the West Midlands identifies Birmingham as being a high risk area for encountering unexploded ordinance. This UXO risk map is attached to this document as

Appendix E. A more detailed study should be carried for the selected route prior to undertaking ground investigation or further development.

2.12 Other Walkover Observations

Notes taken during the Mott MacDonald site walkover on 14 February 2014 are presented on an annotated site plan as Appendix B of this document. Key site walkover observations not reflected elsewhere in this report are listed below:

- A retaining wall on Moor Street Queensway close to the main entrance to Moor Street Station [photo 12]. This may be a relict structure from the former elevated Moor Street Ringway structure.
- A retaining wall on Moor Street forming the western side of Moor Street Station.
- A low level walkway on the northeast corner of the Bull Street/ Corporation Street junction [photo 2]. This structure may represent part of the infilled subway believed to have been present at this location.

Notes taken during the Mott MacDonald site walkover on 20th August 2014 for the additional Route Option 3 section of the route are on an annotated site plan within Appendix B of this document. There are no further key observations to note.

3 Selective Environmental Records

3.1 Polluting Activities

The following reportable pollution incidents and control orders are recorded within the Envirocheck Report as having occurred within 100m of the Route Option alignments:

Table 3-1: Pollution control orders within 100m of the routes.

	Number of Instances			Details
Control measure	Route Option A	Route Option B	Route Option C	
IPPAC	2	1	1	Surface treatment of metals and plastics (effective)
IPPAC	1	1	1	Treatments including use of Hydrogen Cyanide, Hydrogen Sluphide, Mercury, Cadmium and Antimony (surrendered)
LAIPPAC	1	0	0	Hot dip galvanising (issued)
LAPPC	2	3	3	Respraying of road vehicles (authorised)
LAPPC	1	0	1	Processes for the surface treatment of metals (authorised)
LAPPC	1	1	1	Furnaces for the extraction of non-ferrous metal from scrap (authorised)
LAPPC	1	2	1	Iron, steel and non-ferrous metal foundry processes (revoked)
LAPPC	0	1	1	Petrol filling station (authorised)
LAPPC	1	0	0	Cement production processes (authorised)
LAPPC	0	1	1	Coating of metal and plastic (authorised)
LAPPC	0	1	0	Coating of metal and plastic (revoked)
LAPPC	0	2	2	Waste oil burners, less than 0.4MW net rated thermal input (revoked)
LAPPC	0	1	0	Waste derived fuel combustion processes less than 3MW (revoked)
LAPPC	0	1	0	Hot dip galvanising (authorised)
LAPPC	0	1	0	Dry cleaning (authorised)

Key
- IPPAC – Integrated Pollution Prevention and Control
- LAIPPAC – Local Authority Integrated Pollution Prevention and Control
- LAPPC – Local Authority Pollution Prevention Control

Table 3-2: Pollution Incidents to Controlled Waters within 100m of the routes.

Affected Route Option	Category	Cause	Pollutant	Receiving Water
2, 3	3 – Minor	Accidental spillage / leakage	Oils – Diesel	Not Given
2, 3	2 – Significant	Blocked Sewer	Chemicals – Paints / Dyes	Watercourse
2, 3	3 – Minor	Fire	Miscellaneous - Other	Watercourse
1, 3	3 – Minor	Fire	Other Chemicals	Canal
1	3 – Minor	Other Incident / Unknown	Oils – Unknown	Canal
1	3 – Minor	Miscellaneous / Other Pollution Type	Chemicals – Acid	Not Given

Affected Route Option	Category	Cause	Pollutant	Receiving Water
2	3 – Minor	Fire	Miscellaneous – Other	Not Given
2	3 – Minor	Other Incident / Unknown	Oils – Unknown	Canal
1	3 – Minor	Fire	Miscellaneous – Other	Watercourse

3.2 Licensed Industrial Activities

The following potentially polluting industrial activities are recorded within the Envirocheck Report as being within 100m of the Route Option alignments:

Table 3-3: Current and historical industrial land use within 100m of the route alignments

	Route Option A		Route Option B		Route Option C	
Trade description	Active	Inactive	Active	Inactive	Active	Inactive
Air purification equipment	0	1	0	1	0	1
Autogas supplier and installer	0	0	0	1	0	1
Blast cleaning	0	1	0	0	0	0
Cardboard, Box and carton manufacture	0	1	2	0	1	0
Bus and coach operator	1	0	0	0	0	1
Candle manufacture	0	0	0	1	0	1
Car dealers	1	1	2	4	3	3
Carpet cleaners	0	1	0	3	0	3
Catering equipment	0	1	0	1	0	0
Ceramic manufacture	0	0	0	1	0	1
Cleaning services	0	1	0	3	0	2
Computer recycling	0	0	1	0	0	1
Concrete and ready mix mortar	0	1	0	0	0	0
Dry cleaners	0	1	0	2	0	1
Electrical goods sale, manufacture and servicing	1	4	2	2	1	4
Electronic component manufacture	1	0	0	1	0	0
Engineering services	2	6	3	5	2	4
Foam and rubber products	0	0	0	0	0	1
Food product manufacture	0	2	0	2	0	1
Fork lift trucks	0	2	0	3	0	0
French polishing	0	1	0	1	0	1
Furniture manufacture	1	1	0	4	0	4
Garage services	3	8	7	14	4	6
Gunsmith	1	2	1	2	0	2
Hardware manufacture	0	2	1	0	1	0

	Route Option A		Route Option B		Route Option C	
Trade description	Active	Inactive	Active	Inactive	Active	Inactive
Hydraulic equipment servicing & manufacturers / engineers	0	0	0	2	0	1
Industrial machinery	0	0	0	0	0	1
Joinery	1	1	1	1	1	0
Lighting manufacture	0	4	0	2	0	0
Machinery manufacture and repairs	0	2	0	1	0	0
Machine tools	0	1	0	2	0	2
Meat curing	0	0	0	1	0	1
Metal Fabrication	1	2	0	2	0	1
Metal finishing services	1	4	1	5	0	0
Metal working (including foundry processes)	1	3	0	2	1	3
Mould manufacturers	0	1	0	0	0	1
Painting and decorating supplies	1	0	1	0	0	0
Pest and vermin control	1	0	0	0	0	0
Photographic processors	0	2	0	3	0	3
Plant and machinery repairs	0	0	1	0	1	0
Plastic product manufacture	0	1	0	1	0	0
Plastics moulding	0	1	0	1	0	1
Plastics recycling	0	0	0	1	0	1
Pneumatic equipment	1	0	0	1	1	0
Printers	1	4	4	3	0	3
Recycling	0	0	0	1	0	0
Road Haulage	0	1	0	1	0	0
Scrap metal merchants	0	3	0	2	0	1
Screen manufacture	0	1	0	1	0	0
Skin Clinic / Cosmetics	2	0	1	0	0	0
Spray paint and coatings & painting / decorating supplies	1	1	0	2	0	2
Tarpaulin manufacture	0	1	0	1	0	1
Textile manufacture and printing	1	2	2	1	0	2
Valve manufacture	0	1	1	0	1	0
Vehicle breakers	0	2	0	3	0	0
Wireworks	0	1	0	1	0	0

In addition, between twelve and seventeen fuel stations are recorded as being within approximately 1km of each Route Option; of which approximately 50% are noted as being active.

3.3 Waste Activities

Nine waste transfer/treatment sites are noted in the Envirocheck report as being located within 100m of Route Option A, four within 100m of Route Option B and six within 100m of Route Option C; all of these sites were scrapyards and in all cases permissions have expired or have been revoked.

In addition the following waste related activities and/or sites have been identified as being potentially particularly problematic for future site development.

- A landfill site on the former Adderley Brickworks site (approximately 800m to the east of the eastern end of all three Route Options. This site accepted inert, commercial, industrial and household waste until 1937.
- A Chemical treatment works is reported as formerly occupying a site on Green Street Deritend, approximately 130m from Route Option C; the site is assumed to have closed in 2001.
- A waste transfer site authorised to dispose of acid waste is located (and currently operational) on Bordesley Street, approximately 145m from Route Option A.

3.4 Hazardous Substances

The following sites contain or previously contained hazardous substances within vicinity of the Route Options:

- NIHHS (Notification of Installations Handling Hazardous Substances) site recorded as bordering Route Option B on New Canal Street, for Supergas (Midlands) Limited. The site is designated as ceased to be supplied under NIHHS Regulations (1982).
- NIHHS site within 15m of Route Option A on Benacre Drive, for Supergas (Midlands) Limited. The site is designated as ceased to be supplied under NIHHS Regulations (1982).
- Explosive site on Banbury Street identified as The Birmingham Gun Barrel, within 95m of Route Option A and 153m of Route Option B. The site is recorded as Active.

4 History and Historical Land Use

4.1 Archaeology

Interrogation of the Archaeology Data Service (ADS) website shows that throughout the potential development zone there is evidence of Mediaeval and Post Mediaeval occupation and industry.

Key archaeological sites which may pose particular constraints on site development have been identified; these being:

- The site of a 13th century moated manor house between Digbeth and Moat Lane,
- Curzon Street Goods Station (listed) on New Canal Street,
- Moor Street Station (listed) on Moor Street Queensway,
- St. Martins Church (listed) on Park Street/Moat Lane,
- The medieval Crown Inn (listed) on High Street Deritend adjacent to the junction with Heath Mill Lane,
- An in-filled post medieval water channel located close to the High Street Deritend crossing of the River Rea, and,
- A public convenience built circa 1880-90 set within arch of a railway viaduct on Meriden Street.

4.2 Historical land use

Historical land use along the Route Options has been determined based on 1:2,500 and 1:1,250 scale historical Ordinance Survey mapping from 1890 up to 1991, procured as part of the Envirocheck Report for the site. For the purposes of reviewing site history the route has been split into sections based on primary current land use as follows:

Table 4-1: Land use zones

Section	Route Option A	Route Option B	Route Option C
City Centre	Start to Ch10450m (300m)	Start to Ch10070m (300m)	Start to Ch10480m (300m)
Parkland/landscaped green areas	Ch10450 to Ch10950m (500m)	Ch10070 to Ch10570m (500m)	NA
Major Highway routes	NA	Ch11070 to Ch11660m (590m)	Ch10480m to Ch11630m (1150m)
Industrialised areas	Ch10950m to End (1050m)	Ch10570 to Ch11070m (500m) and Ch11660 to End (340m)	Ch11630m to End (370m)

The following tables outline key developments along the three Route Options. Bold text indicating key observations made from the historical mapping which may impact significantly on future route development.

Table 4-2: Historical development along Route Option A

Map		City Centre Start to Ch10450m (300m)	Parkland / landscaped green areas Ch10450 to Ch10950m (500m)	Industrialised areas Ch10950m to End (1050m)
1890	1:2,500	Predominantly residential development. Railway tunnel between the site of Moor Street station (site) and Snow Hill Station in existence. On street tramway from the junction of Bull Street and the former route of Albert Street to the end of the route section.	Predominantly residential with areas of parkland. Railway dominated environment to the east of New Canal Street. On street tramway along Albert Street, Duddeston Road and Curzon Street. Railway viaduct present crossing the route at junction of New Canal Street and Fazeley Street.	Predominantly industrial land use, including wharfs (associated with the Birmingham Canal and the Warwick and Birmingham Canal), Metal working, Timber yards, a proof house, breweries, chemical works, brick works and a gas works. Railway Viaduct crossing the route at the junction of Fazeley Street and Heath Mill Lane already noted as being disused.
1927	1:2,500	On street tramway extended along Corporation Street.	Reduced extent of the tramway along Albert Street only. Tramway now present along Fazeley Street up to Liverpool Street junction.	Large brickworks to the east of the route end no longer present.
1937	1:2,500	No significant change.	Area around Dudeston Row and New Canal Street becoming more industrialised, including the construction of a large Machine Tool Works.	Large bus depot constructed on the junction of Adderley Street and Liverpool Street.
1952	1:2,500	Area around Albert Street becoming more industrialised, including the construction of an electrical sub-station and a plastic works.	Further industrialisation around Albert Street and New Canal Street. Including construction of an oil depot within Curzon Street Goods Station and metal working facilities. Tramway no longer recorded as being present.	Further industrialisation to the south of Fazeley Street
1960	1:1,250	Tramway no longer recorded as being present.	No significant change	-
1965	1:1,250	-	-	Gas works no longer present to the south of Adderley Street.
1969	1:1,250	Area around Bull Street becoming more commercialised	Minor highway layouts. Dudeston Row becomes part of Albert Street.	-
1970	1:1,250	**Construction of Moor Street Ringway**, Albert Street passing underneath the elevated highway structure.	No significant change	-
1978	1:1,250	Construction of a multi storey car park immediately to the north of Albert Street.	Northern section of Curzon Street Goods Station closed. Curzon Street goods station and the oil depot on Albert Street (formerly Dudeston Row) closed.	-
1991/ 1992	1:1,250	Albert Street realigned to the north of the Bull Street/High Street junction and New Meeting Street truncated at its northern end (becoming a footpath only)	-	Birmingham ringroad shown as being constructed to the east of the eastern end of the site.

Post 1992: **Elevated Moor Street Ringway demolished and replaced with Moor Street Queensway in 2002**

Table 4-3: Historical developments along Route Option B

Map		City Centre Start to Ch10070m (300m)	Parkland / landscaped green areas Ch10070 to Ch10570m (500m)	Industrialised area Ch10570 to Ch11070m (500m)	Major Highway routes Ch11070 to Ch11660m (590m)	Industrialised area Ch11660 to End (340m)
1890	1:2,500	Predominantly residential development. Railway tunnel between the site of Moor Street station (site) and Snow Hill Station in existence**.** On street tramway from the junction of Bull Street and the former route of Albert Street to the end of the route section.	Predominantly residential with areas of parkland. Railway dominated environment to the east of New Canal Street. On street tramway along Albert Street, Duddeston Road and Curzon Street. Railway viaduct present crossing the route at junction of New Canal Street and Fazeley Street.	Mixed industrial and residential land use, including Solar Works, hide and skin markets, rolling mill (metal works), iron works and wharfs (timber and slate) associated with Birmingham Canal. Land use becomes less industrial along Meriden Street. **Birmingham Canal within 15m of New Canal Street.** On-street tramway joins New Canal Street at Bordesley Street junction and continues along New Canal Street and Meriden Street into Digbeth. Railway viaduct for Great Western Railway crossing the route south of Bordesley Street and New Canal Street junction.	Predominantly residential development with light industry relating to metal working. **Railway tunnels to New Street Station and Snow Hill Station in existence.** On-street tramway present on High Street Deritend between the junction with Rea Street and the end of the route section. On-street tramway crosses Digbeth at Meriden Street and Smithfield Street junction.	Predominantly industrial land use at eastern end of route, including wharfs (associated with the Birmingham Canal and the Warwick and Birmingham Canal), Metal working, Timber yards, a proof house, breweries, chemical works, brick works and a gas works immediately adjacent to the scheme end. Railway Viaduct crossing the route at the junction of Fazeley Street and Heath Mill Lane already noted as being disused.
1927	1:2,500	On street tramway extended along Corporation Street.	Reduced extent of the tramway along Albert Street only. Tramway extended along Fazeley Street to Liverpool Street junction.	On-street tramway no longer present along New Canal Street and Meriden Street. Widening of railway line crossing New Canal Street at Fazeley Street junction. ***Elan Aqueduct (B.C.W.W.)* labelled on New Canal Street suggesting it runs beneath New Canal Street and possibly Meriden Street. If the *Elan Aqueduct* is still present then this of Major Significance and affects all three routes.** Part of Birmingham Canal wharf closest to New Canal Street appears to have been infillled.	On street tramway extended along Digbeth High Street.	Large brickworks to the east of the route end no longer present.
1937	1:2,500	No significant change.	Area around Dudeston Row and New Canal Street becoming more industrialised, including the construction of a large Machine Tool Works.	Solar Works now identified as electrical fittings. Metal works labelled at the southern end of Meriden Street. General industrialisation has taken place along Meriden Street. *Elan Aquaduct* no longer identified on OS mapping. Railway infrastructure extended to the south of Moor Street Station, including construction of additional track and a goods shed.	Increasing industrialisation; mostly metal working, but also including food manufacture and a bus depot.	Large bus depot constructed on the junction of Adderley Street and Liverpool Street.
1952	1:2,500	Area around Albert Street becoming more industrialised, including the construction of an electrical sub-station and a plastic works.	Further industrialisation around Albert Street and New Canal Street. Including construction of an oil depot within Curzon Street Goods Station and metal working facilities. Tramway no longer recorded as being present.	Several new industrial works identified along New Canal Street and Meriden Street, including engineering works, radiator works, bakery, mineral water works, animal byproducts factory, warehouses, and garages. A structure is shown on the alignment of Meriden Street which is subsequently labelled as a tank; it is assumed that this is associated with railway infrastructure and is located on the railway viaduct.	Further industrialisation; mostly metal working, but also including food manufacture and chemical plants. Tramway recorded on Digbeth High Street up to the junction with Rea Street.	Further industrialisation to the south of Fazeley Street
1960	1:1,250	Tramway no longer recorded as being present.	No significant change	Most industries now labelled as *Works and Warehouses*.	Tramway no longer recorded as being present.	-
1963	1:1,250	-	-	Birmingham Canal wharfs further infillled between New Canal Street and Fazeley Street.		
1965	1:1,250	-	-	-	-	Gas works no longer present to the south of Adderley Street.
1969	1:1,250	Area around Bull Street becoming more commercialised	Minor highway layouts. Dudeston Row becomes part of Albert Street.	-	-	-
1970	1:1,250	**Construction of Moor Street Ringway**, Albert Street passing underneath the elevated highway structure.	No significant change	-	-	-
1978	1:1,250	Construction of a multi storey car park immediately to the north of Albert Street.	Northern section of Curzon Street Goods Station closed. Curzon Street goods station and the oil depot on Albert Street (formerly Dudeston Row) closed.	Minor changes in industry with the area predominantly occupied by *Works* and *Factories*. Spur lines to the south of Moor Street Station no longer shown as being present.	-	-
1991/1992	1:1,250	Albert Street realigned to the north of the Bull Street/High Street junction and New Meeting Street truncated at its northern end (becoming a footpath only)	-	Benacre Drive constructed to give access to industrial units to the east of New Canal Street.	Minor alterations to road alignments. Rail depot and track adjacent to Moor Street Station no longer shown.	Birmingham ringroad shown as being constructed to the east of the eastern end of the site.

Post 1992: **Elevated Moor Street Ringway demolished and replaced with Moor Street Queensway in 2002.**

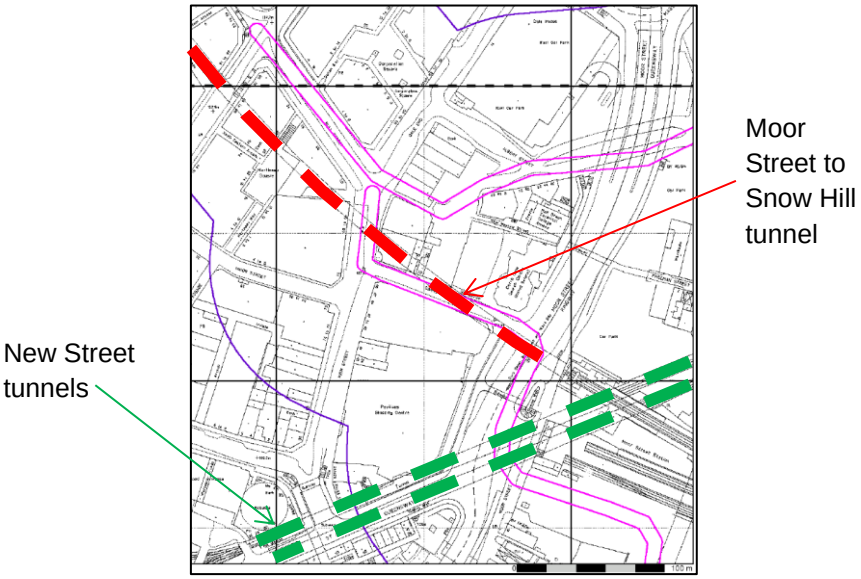
Table 4-4: Historical development along Route Option C

Map		City Centre Start to Ch10480m (300m)	Major Highway routes Ch10480m to Ch11630m (1150m)	Industrialised areas Ch11630m to End (370m)
1890	1:2,500	Predominantly residential development. **Railway tunnel to Snow Hill Station in existence, approximately following the alignment of Carrs Lane**	Predominantly residential development with light industry (particularly at the eastern end of the route section). Mapped industry mostly relating to the metal working industry. **Railway tunnels to New Street Station and Snow Hill Station in existence.** On-street tramway present on High Street Deritend between the junction with Rea Street and the end of the route section. On-street tramway crosses Digbeth at Meriden Street and Smithfield Street junction.	Mixed residential and industrial land use. Industry includes chemical works, a brewery, gas works and a brick works, but is mostly related to metal working. Railway infrastructure crosses the route at the western end of Adderley Street whilst the Adderley street crossing of the Warwick and Birmingham Canal defines the easternmost extent of the route.
1927	1:2,500	On street tramway from the junction of Bull Street and High Street to the end of the route section.	Moor Street Station Constructed. On street tramway extended along Digbeth High Street.	Large brickworks to the east of the route end no longer present.
1937	1:2,500	No significant change	Increasing industrialisation; mostly metal working, but also including food manufacture and a bus depot. Railway infrastructure extended to the south of Moor Street Station, including construction of additional track and a goods shed.	Large bus depot constructed on the junction of Adderley Street and Liverpool Street.
1952	1:2,500	Area around Carrs Lane becoming more industrialised	Further industrialisation; mostly metal working, but also including food manufacture and chemical plants. Tramway recorded on Digbeth High Street up to the junction with Rea Street.	Area almost entirely industrialised (generally metal working related).
1960	1:1,250	Tramway no longer recorded as being present.	Tramway no longer recorded as being present.	-
1965	1:1,250	-	-	Gas works no longer present to the south of Adderley Street.
1969	1:1,250	Area around Bull Street becoming more commercialised	-	No significant change.
1970	1:1,250	-	**Moor Street Ringway Constructed.** Bull Ring Centre development close to the eastern end of the route section.	No significant change.
1971	1:2,500	Commercialisation continues, including redevelopment of the Martinaeu Street area. Road layout altered as part of the redevelopment	-	No significant change.
1978	1:1,250	-	Minor alterations to road alignments. Rail depot and track adjacent to Moor Street Station no longer shown.	No significant change
1991	1:1,250	-	-	Birmingham ring road shown as being constructed to the east of the eastern end of the route.

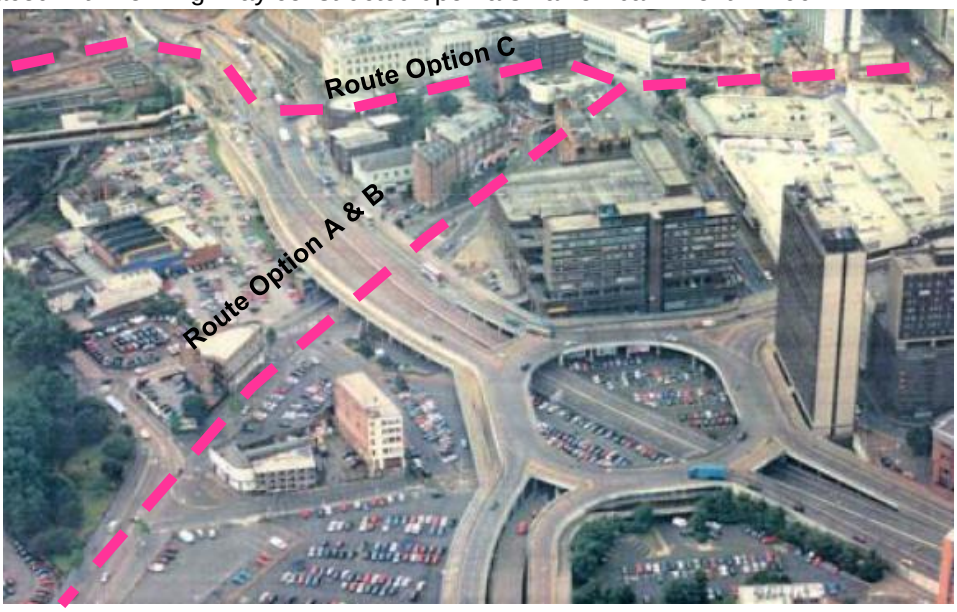
Post 1992: **Elevated Moor Street Ringway demolished and replaced with Moor Street Queensway in 2002.**

Key observations identified during review of historical mapping are as follows:

- Presence of railway tunnels in the vicinity of Moor Street station and approximately along the route of Carrs Lane.

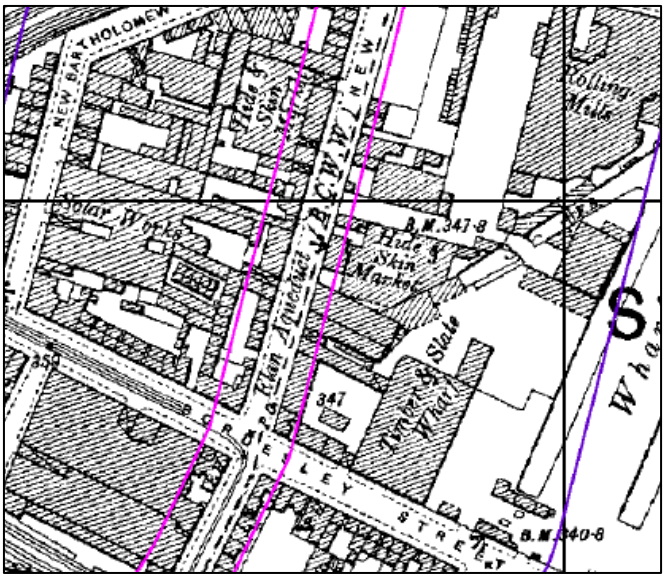


- Construction of the elevated Moor Street Ringway, and subsequent demolition. The elevated highway was replaced with new highway constructed upon a small embankment in 2002.



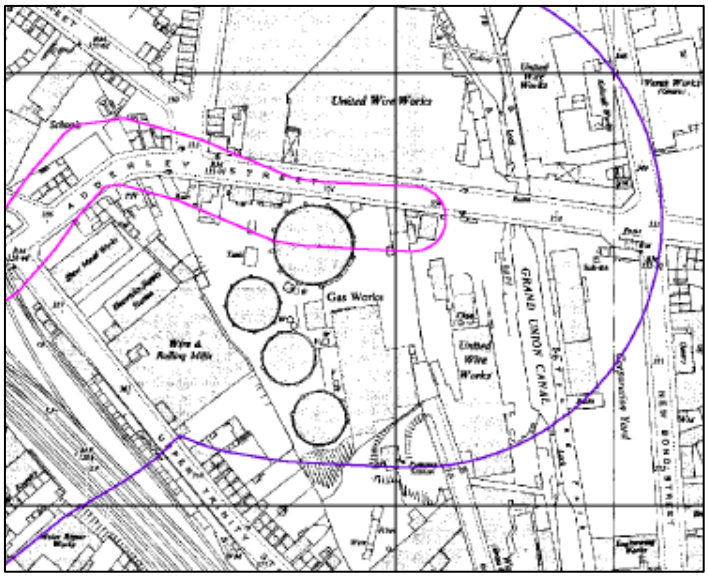
Pre 2002 layout of Masshouse Circus and Moor Street Ringway
Source: Birmingham City Council Website

- Suspected presence of Elan Aqueduct running underneath Meriden Street and New Canal Street as observed on historical OS mapping.



Source: Historical OS mapping available within obtained Envirocheck report for Route Option B, Published 1905, 1:2,500 scale

- Gas Works identified on historical OS at the eastern end of the Route Options on Adderley Street. Identified on OS mapping between 1890 and 1952. Potential source of contamination.



Source: Historical OS mapping available within obtained Envirocheck report for Route Option B, Published 1952, 1:2,500 scale

5 Contamination and Environmental Considerations

The primary legislative regime under which historic contaminated land is managed in the UK is Part IIA of the Environmental Protection Act (EPA), 1990. The framework for the assessment of potential land contamination adopted in this report is based on current guidance documents regarding the implementation of Part IIA of the EPA and the assessment of potentially contaminated land, with particular reference to:

- Department of the Environment Food and Rural Affairs (DEFRA) (2012)[xv]:"*Environmental Protection Act 1990: Part 2A, Contaminated Land Statutory Guidance*", April 2012;
- Environment Agency (2008)[xvi]:"*Human Health Toxicological Assessment of Contaminants in Soil*", Science Report – SC050021/SR2;
- Environment Agency (2008) [xvii]: "*Updated Technical Background to the CLEA Model*", Science Report - SC050021/SR3;
- British Standard (BS) 10175:2011[xviii], "*Investigation of Potentially Contaminated Sites"*;
- Environment Agency (2012)[xix]. "*Groundwater Protection Policy and Practice, GP3"*;
- Construction Industry Research and Information Association (2001)[xx] : "*Contaminated land risk assessment: A guide to good practice*", CIRIA C552;
- Department for Communities and Local Government (2012)[xxi]: "*National Planning Policy Framework*".

5.1 Statutory Requirements

Part IIA principally deals with sites where individual historic contamination linkages present a "Significant Possibility of Significant Harm" (SPOSH) or a Significant Possibility of Significant Pollution to Controlled Waters (SPOSPCOW) representing an unacceptable level of contamination risk for each linkage. The Part IIA clean-up is the minimum which can be done on a cost basis to make and keep the site in a "just safe" condition for an existing use.

Elimination of liability under Part IIA is not always achievable largely because of the inherent risk basis of the statutory regime, the technical difficulty in establishing levels of contamination that are likely to represent SPOSH, and the variable distribution of contamination at many sites. Statutory guidance on Part IIA (DEFRA, 2012) recognises that sites require prioritisation by Local Authorities under the statutory Part IIA site inspection programme to ensure that only those sites likely to present the greatest risks are identified. However it should be recognised that considerable investigation is often required to establish whether sites are likely to meet the definition of contaminated land under Part IIA. Such investigation may be beyond the scope of project budgets for nominally "low risk sites" necessitating judgement on an acceptable level of investigation. Since the designation of Contaminated Land is the responsibility of the local Authority, it is advised that consensus is sought on any recommendations regarding the significance of contaminated land risks and remedial measures through consultation with the Regulator(s).

S 161 of the Water Resources Act 1991 states that the Environment Agency can recover clean-up costs on person(s) who caused or knowingly permitted the entry or presence of any poisonous, noxious or polluting matter or any solid waste into controlled waters. Contamination and environmental considerations are studied by developing a conceptual model of the site that describes the environmental features of the site together with the expected interaction of potential contamination sources and the wider environment.

5.2 Planning Requirements

The National Planning Policy Framework (Department for Communities and Local Government, 2012) includes the following policies in relation to contaminated land:

Policy 109: "The planning system should contribute to and enhance the natural and local environment by:

- preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by unacceptable levels of soil, air, water or noise pollution or land instability; and
- remediating and mitigating despoiled, degraded, derelict, contaminated and unstable land, where appropriate"

Policy 120: "To prevent unacceptable risks from pollution and land instability, planning policies and decisions should ensure that new development is appropriate for its location. The effects (including cumulative effects) of pollution on health, the natural environment or general amenity, and the potential sensitivity of the area or proposed development to adverse effects from pollution, should be taken into account. Where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner."

Policy 121: "Planning policies and decisions should also ensure that:

- the site is suitable for its new use taking account of ground conditions and land instability, including from natural hazards or former activities such as mining, pollution arising from previous uses and any proposals for mitigation including land remediation or impacts on the natural environment arising from that remediation;
- after remediation, as a minimum, land should not be capable of being determined as contaminated land under Part IIA of the Environmental Protection Act 1990; and
- adequate site investigation information, prepared by a competent person, is presented."

The glossary states the following relation to "site investigation information":

- "Site investigation information: Includes a risk assessment of land potentially affected by contamination, or ground stability and slope stability reports, as appropriate. All investigations of land potentially affected by contamination should be carried out in accordance with established procedures [such as BS10175 (2011) Code of Practice for the Investigation of Potentially Contaminated Sites]. The minimum information that should be provided by an applicant is the report of a desk study and site reconnaissance."

Birmingham City Council (2009) 'Guidance on Development of Contaminated Land'[xxii] indicates that development often occurs on previously developed land (brownfield land). Such land, due to its previous use may have been subjected to contamination, which will affect the new development and or the environment if not dealt with. The planning authority can require applicants to demonstrate that the land to be developed is free from contamination or can be remediated to an extent that contamination poses no risks to the end users and the wider environment. It is the developer's responsibility to ensure that development is safe and suitable for the intended future use.

The guidance goes onto state that:

"*Any land previously used for industrial purposes should be regarded as potentially contaminated, as the processes carried out may have caused the releases of toxic or noxious materials to the ground. In particular, land associated with former gas works, metal processing, refuse disposal, sewage works, oil storage and production as well as infilled pits or quarries will almost certainly require further investigation.*"

5.3 Qualitative Contamination Risk Assessment

A qualitative risk assessment in accordance with CIRIA C552 (2001) has been undertaken. This is described below:

A key element of an environmental risk assessment is the development of a conceptual model which is done by undertaking a Source –Pathway – Receptor analysis of the Site:

- **Sources** (S) are potential or known contaminant sources e.g. a former land use;
- **Pathways** (P) are environmental systems thorough which a contaminant could migrate e.g. air, groundwater;
- **Receptors** (R) are sensitive environmental receptors that could be adversely affected by a contaminant. E.g., Site occupiers, groundwater resources.

Where a source, relevant pathway and receptor are present, a pollutant linkage is considered to exist whereby there is a circumstance through which environmental harm could occur and a potential environmental liability is considered to exist. The conceptual model for the site is presented in Table 5-1. Probability, consequence and risk criteria are based on CIRIA C552 (2001) and reproduced in Appendix F.

Table 5-1: Conceptual Model for the Birmingham Eastside Metro routes

Source	Receptor	Pathway	Consequence	Probability	Risk	Comments
S1: Historical industrial land use in close proximity to the site, such as railway infrastructure, oil depots, chemical works and metal working S2: Leaks and spills from vehicles operating on the existing road network S3: Blacktop surfaces S4: Made ground, including demolition rubble, buried structures, historical road surfaces etc. S5: Historical industrial land use in the vicinity of the site, such as gasworks, metal works and railway depots	R1: Groundwater residing in the permeable natural deposits	P1: Horizontal and Vertical migration of leachate through permeable soils and rock P7: Migration of contaminants along engineered preferential pathways such as service trenches and drains	Medium	Likely	Moderate	The underlying Bromsgrove Sandstone Formation is classified as a Principal Aquifer by the Environment Agency. This aquifer is highly vulnerable to pollution as its permeability has the potential to allow liquid pollutants to transmit. Until Ground Investigation works are undertaken to rule out the presence of on-site contamination it should be assumed that the groundwater residing in the aquifer is at MODERATE risk from contamination. Secondary A aquifers of Alluvium and Glaciofluvial Deposits and Secondary B aquifer of Mercia Mudstone are less permeable and therefore groundwater residing in these formations are at lower risk from contamination.
	R2: Surface water bodies such as the Grand Union Canal and the River Rea	P2: Surface runoff P7: Migration of contaminants along engineered preferential pathways such as service trenches and drains	Medium	Likely	Moderate	All three routes cross surface water features. Due to the high number of potential contaminant sites the risk to surface water features due to run-off may be considered to be MODERATE.
	R3: Sub-surface infrastructure	P1: Horizontal and Vertical migration of leachate through permeable soils and rock P6: Direct contact with contaminated soils P7: Migration of contaminants along engineered preferential pathways such as service trenches and drains	Medium	Likely	Moderate	Mercia Mudstone is known to contain discrete lenses of evaporitic deposits which are likely to have a high sulphate content. Until Ground Investigation works are undertaken to rule out the presence of aggressive conditions towards buried concrete it should be assumed that sub surface infrastructure is at MODERATE risk from attack.
	R4: Flora and Fauna	P3: Root uptake	Mild	Low likelihood	Low	Green areas form a very small proportion of the proposed route zone. These areas have been recently redeveloped and are likely to have been remediated to remove high levels of contamination; therefore the risk of contamination affecting flora and fauna is considered to be low.
	R5: Construction and maintenance workers	P4: Human uptake pathways P5: Vertical and lateral migration of	Medium	Likely	Moderate	It is possible that construction workers will come into contact with contaminants and ground gas residing in soils present on site. Until Ground Investigation works are undertaken to rule out

Source	Receptor	Pathway	Consequence	Probability	Risk	Comments
		volatile vapours and ground gas				the presence of on-site contamination it should be assumed that construction workers are at MODERATE risk from contamination.
	R6: Final end users and the public	P4: Human uptake pathways	Medium	Unlikely	Low	Historical land uses such as metal working, chemical works and an oil depot may have resulted in harmful substances migrating into on-site soils. Redevelopment of the site is unlikely to leave significant quantities of exposed soils therefore contamination risk to the public is considered to be LOW.

6 Preliminary Engineering Considerations

6.1 Proposed Development

It is proposed to provide a tram link between the currently under construction Midland Metro Phase 1, Birmingham City Extension (BCCE) and the proposed Park and Ride site on Adderley Street (currently a bus depot). Route Option A serves the proposed High Speed 2 station on the former Curzon Street Goods Station site and passes through congested industrial areas of the city, whilst Route Option C is located primarily on large highways. Route Option B provides a composite route combining the western section of Route Option A serving the proposed High Speed 2 station, and the eastern section of Route Option C along a large highway.

6.2 Site Constraints

- The majority of the route alignments are constrained by existing highway layouts. Route Option A passes through narrow city centre streets at its western end and through narrow streets predominantly serving industrial units and properties for the majority of the route length. Currently the industrial areas are serviced by large vehicles which may pose problems for tram movement in busy periods. Route Option B is constrained by the narrow city centre streets at its western end, follows wide industrial streets in the middle section of the route, and follow wide highways of s the B4100 before entering the industrial area of Adderley Street. Route Option C predominantly follows the route of the B4100 which serves as a major route into the city; during rush hour periods traffic on these routes may result in problems for tram movement.
- Railway bridges across the alignment at Ch.10960m and Ch.10575m (Route Option A & B respectively), Ch.10880m (Route Option B), Ch.11715m and Ch.11690 (Route Option B & C respectively), and a disused bridge at Ch.11760m and Ch.11730m (Route Option B & C respectively),
- Alignment crossing of the River Rea at Ch.11340m (Route Option A), Ch.11325m (Route Option B). and Ch.11310m (Route Option C), The River Rea is set within a hard banked engineered channel which may not precisely reflect the historical river route,
- Alignment crossing of the Digbeth Branch of the Birmingham Canal at Ch.11130m (Route Option A),
- The presence of the Birmingham and Warwick Canal defining the eastern end of the site at Ch.12000m.
- The presence of railway tunnels in the vicinity of Moor Street station and the city centre sections of the route alignments,
- Possible presence of tunnels immediately to the south of High Street Deritend as indicated by the presence of tunnel related ground investigation data on the BGS website,
- The possible presence of an aquaduct along New Canal Street.
- The potential presence of an infilled subway at the junction of Bull Street and Corporation Street at the extreme western end of the routes. It should be noted that no subway is shown on historical mapping for the site but the presence of such a structure was considered to be credible during preliminary works for the BCCE route. A low level walkway is present in this location which may be part of the former subway structure.
- Building demolition required at the northern end of New Meeting Street for Route Option A and B,
- Building demolition required at the Fazeley Street junction with New Canal Street (Route Option A),
- Risk of unexploded ordinance in an area of Birmingham historically dominated by industry and railway infrastructure.
- Buried services are likely to be present below highways along both Route Options.
- Two number retaining walls are present in the vicinity of Moor Street Station, adjacent to the alignment of Route Option C, and,

- Gradients at the western end of the site may be problematic, requiring careful vertical alignment design.

6.3 Ground Constraints

During compilation of this Desk Study Report the following potential ground related constraints have been identified:

Table 6-1: Ground constraints

Constraint	Impact
The potential for thick, highly variable and poorly compacted Infilled or Made Ground particularly around the Moor Street Queensway area.	General excessive settlement under loading. Thick Made Ground may necessitate ground improvement works to provide adequate support to trackslab, and the use of piled foundations for the supporting of other infrastructure (OLE masts etc)
The presence of Glaciofluvial Deposits across much of the site, including deep deposits associated with the infilled paleovalley at the extreme eastern end of the site.	Unsupported excavations are likely to be unstable, particularly if groundwater is flowing into the excavation. Generally the Glaciofluvial deposits represent good founding deposits of trackslab and OLE posts, however, localised cohesive lenses may be soft, compressible and unsuitable as loadbearing strata due to the potential for large displacements under loading.
The presence of Alluvium through the centre of the site in close proximity to the River Rea	Highly compressible normally consolidated deposits dominated by soft clay with localised deposits of peat are generally unsuitable as founding deposits due to the potential for large displacements under loading. Ground improvement measures would be necessary if shallow foundations were to be used in these areas, whilst structures sensitive to displacement such as track slab may have to be piled into underlying competent deposits or require ground improvement to stiffen weak soils.
The presence of Bromsgrove Sandstone underlying the north western half of the site.	These deposits may be found to be weathered in near surface deposits to a residual soil state. This weathering may vary with depth resulting in interbedded deposits of sand and sandstone, with subordinate bands of mudstone and clay. The presence of sandstone close to the ground surface, whilst beneficial for shallow foundations, may impact on vertical alignment of the tramway if excavation of intact rock is found to be necessary. Subordinate mudstone and clay bands may degrade significantly if left exposed to wet weather.
The presence of Mercia Mudstone underlying the south eastern half of the site.	These deposits may be found to be weathered in near surface deposits to a residual soil state. This weathering may vary with depth resulting in interbedded mudstone and clay. Mudstone close to the ground surface, whilst beneficial for shallow foundations, may degrade significantly if left exposed to wet weather. Subordinate evaporitic deposits such as gypsum may result in aggressive conditions for buried concrete.
The potential for buried structures and buried highway construction around Moor Street Queensway.	The presence of buried structures may impact on vertical track alignment design, and may necessitate excavation

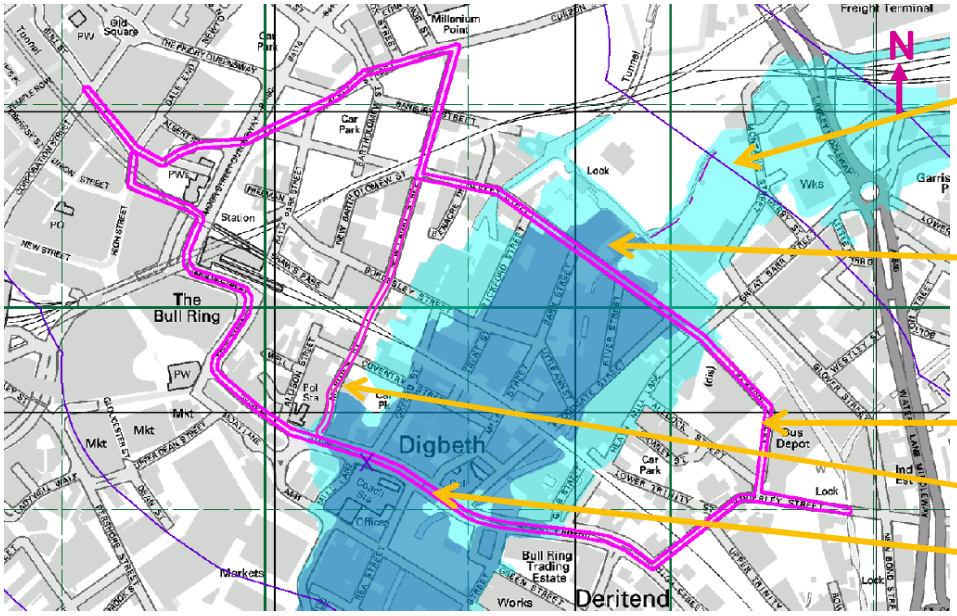
Constraint	Impact
Potential buried structures around former Banbury Street and Bartholomew Street residential properties opposite Curzon Street Station, which may include infillled basement structures.	and replacement with engineered compacted granular fill. If below ground obstructions remain in place "hard spots" under the track alignment may result in reduced long term settlement in discrete areas and result in poor ride quality.
The potential for concrete slabs or localised voids within the highway, as encountered elsewhere within the city centre during Midland Metro ground investigation works.	The presence of buried services such as a buried aqueduct, may require impact assessments, diversions or monitoring during construction works.
The potential for a buried aqueduct structure along the alignment of New Canal Street.	
Potential basements under existing footways along Meriden Street.	
The potential for poorly infilled water channels associated with historical industrial development on the banks of the River Rea and poor backfill behind the existing river bank walls, and infillled canal channels adjacent to New Canal Street.	Made or infilled ground has the potential to be highly variable and poorly consolidated giving rise to the potential for low strength founding deposits which compress significantly under loading.
The potential for a poorly infilled moat associated with a former manor house site in the vicinity of Moat Street.	Additionally in these historically low-lying or infilled locations problematic soils such as soft clay or silt and peat may be anticipated. These soils also represent poor founding materials for structures generally being low strength and prone to large displacements under loading.
	If poor infill material or problematic soils exist deep foundation solutions may be necessary in the vicinity of river crossings for track slab sections, OLE posts, and other structures.
Groundwater levels in the vicinity of the site are currently unknown.	The presence of perched or particularly high groundwater may result in instability of unsupported excavations and difficulties when pouring concrete.

6.4 Environmental Constraints

During compilation of this Desk Study Report the following potential environmental related constraints have been identified:

- Significant sections of the three route alignments fall within 1:100 and 1:1000 year flood event zones as shown below:

Figure A-1: Flood risk map (not to scale)



Source: Envirocheck Report, © Crown Copyright. All rights reserved License Number 100022432

- The Principal Aquifer underlying the site (Bromsgrove Sandstone Formation) and associated Source Protection Zones must be protected in order to prevent migration of contaminants from overlying Made Ground,
- Historical industrial land use in the vicinity of the site, particularly in the industrialised zone including many metal works and a gas works, is likely to be a source of contamination and may be an indication of possible on site contamination, and,
- The potential for buried highway structures in the Moor Street Queensway area which may contain coal tar, requiring disposal at an appropriately accredited waste disposal site,

6.5 Sustainable development Considerations

The following sustainability related opportunities may be used to differentiate between the three proposed Route Options:

- The opportunity to remediate potentially contaminated land (particularly Route Option A)
- Recovery of buried concrete with crushing and screening may allow recovery of coarse granular fill for reuse onsite. This opportunity is particularly likely along major highways that form the majority of Route Option C and part of Route Option B.
- Opportunity for an integrated public transport network at the proposed High Speed 2 station (Route Option A and B).
- Potential shallow sandstone in some sections of all Route Options will result in better strength formation, minimising the need for ground improvement or deep foundation solutions.
- Use of slab track can be designed to accommodate localised variations of formation strength or stiffness, including problematic Made Ground and soft or compressible clay, and minimise excavation and disposal of excess waste material.

Other sustainability issues should be considered at a high level as part of the Eastside master plan.

7 Recommendations

Upon confirmation of the development Route Option the following works should be considered to develop understanding of constraints impacting on delivery of the Midland Metro Phase 2 line.

7.1 Non-intrusive Investigation

- GPR survey of the route corridor to identify the presence of buried structures and below ground voids,
- GPR and utility survey of the route corridor to identify the presence of buried services,
- GPR survey of basement walls and retaining walls in order to determine geometry, structural capacity and suitability for continued use as part of the permanent works,
- GPR survey of building walls at any OLE building fixing locations in order to accurately determine geometry and structural capacity for the resisting of applied OLE loading, and,
- Visual condition survey of structures and existing buildings (internal and external), and to check for basements under existing footways.

7.2 Intrusive Ground Investigation

The scope of intrusive ground investigation should be confirmed after review of non-intrusive GPR survey works is undertaken to aid effective targeting of the ground investigation. The works are likely to include, but may not be limited to the following:

- Deep dynamic sampler boreholes with rotary follow on, and windowless sampler boreholes to confirm the ground model for the site, for in-situ Standard Penetration Testing and for the collection of soil and groundwater samples for laboratory testing,
- Inspection pits for identification of structure foundations,
- In-situ stiffness testing in the highway to determine stiffness characteristics of subformation layers (dynamic probing, static plate load testing, dynamic plate load testing etc.),
- Concrete coring through concrete obstructions and structures,
- Geotechnical laboratory testing to determine geotechnical parameters,
- Chemical testing to determine concrete design requirements, and,
- Contamination testing in order to determine risk to human health and the environment and to determine waste acceptance criteria.

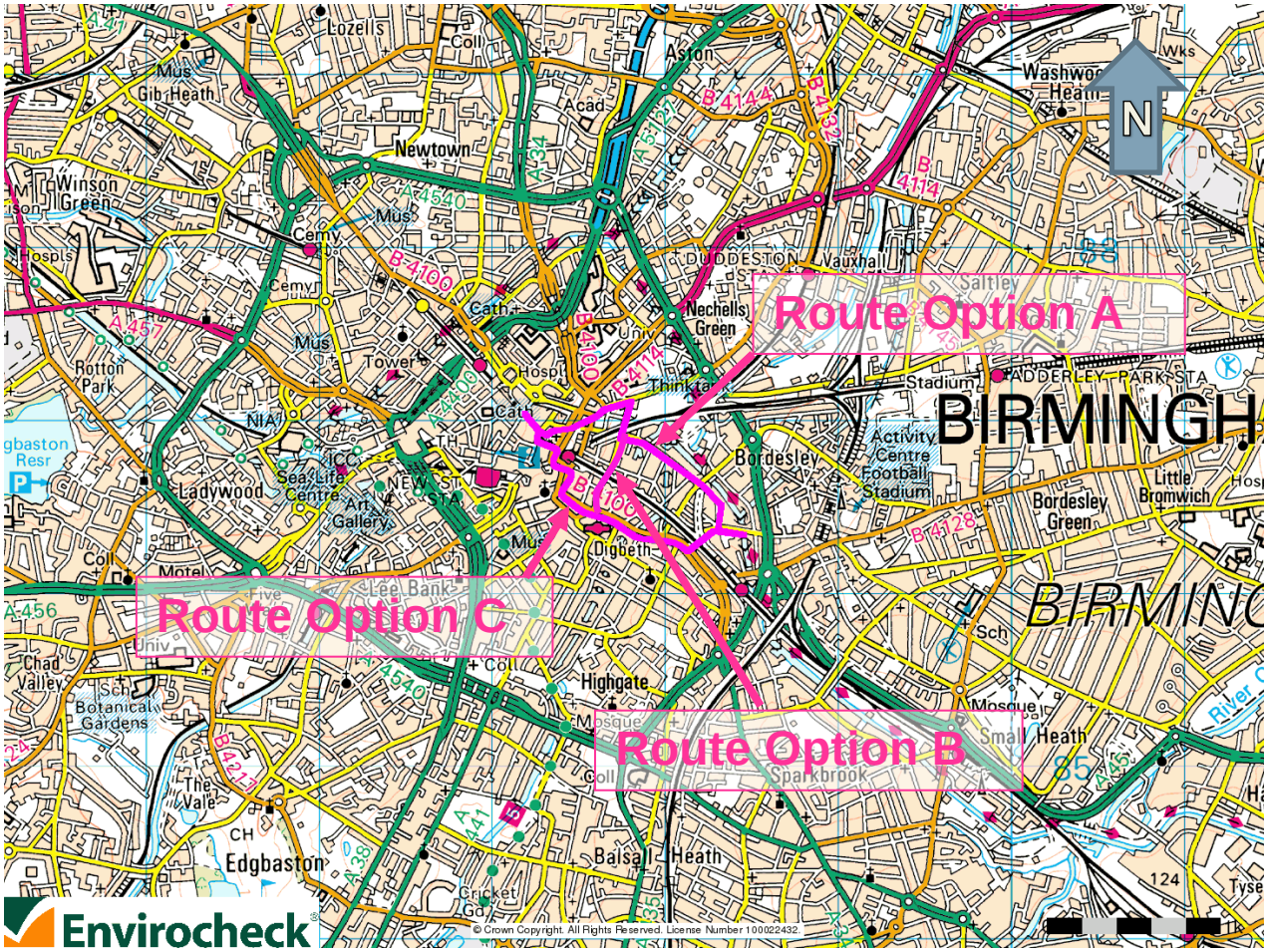
7.3 Other requirements

- Liaison with Network Rail for working in the vicinity of tunnel structures and retaining walls,
- Liaison with Birmingham City Council (and their highway maintenance contractor) for traffic management arrangements,
- Liaison with High Speed 2 station developers,
- Further investigation of possible tunnels in the vicinity of Digbeth and High Street Deritend.
- Collation and review of as-build drawings for structures in the vicinity of the site, and,
- Collation and review of utility plans.

Appendices

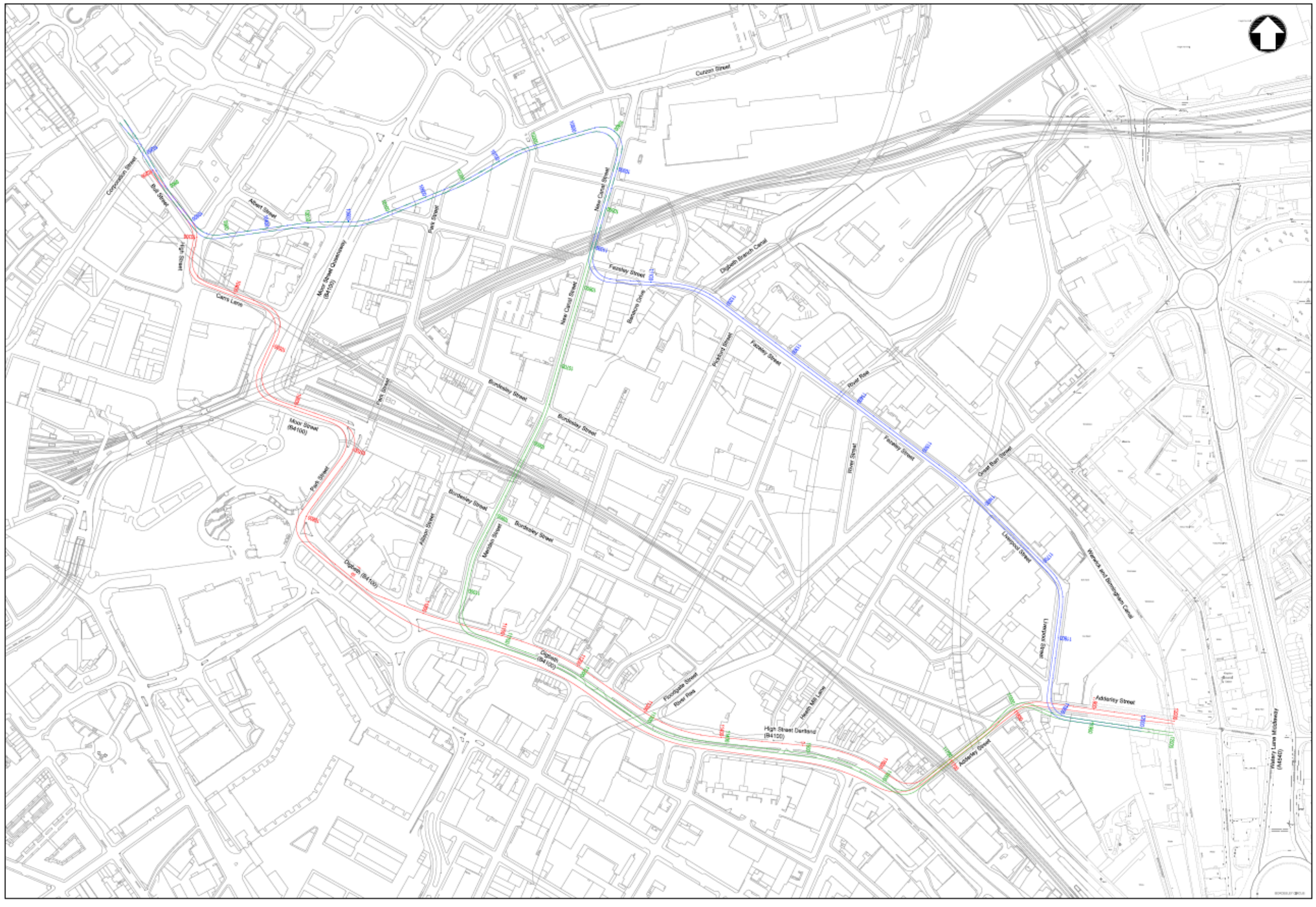
Appendix A. Route Details

A.1 Site location



A.2 Route Options

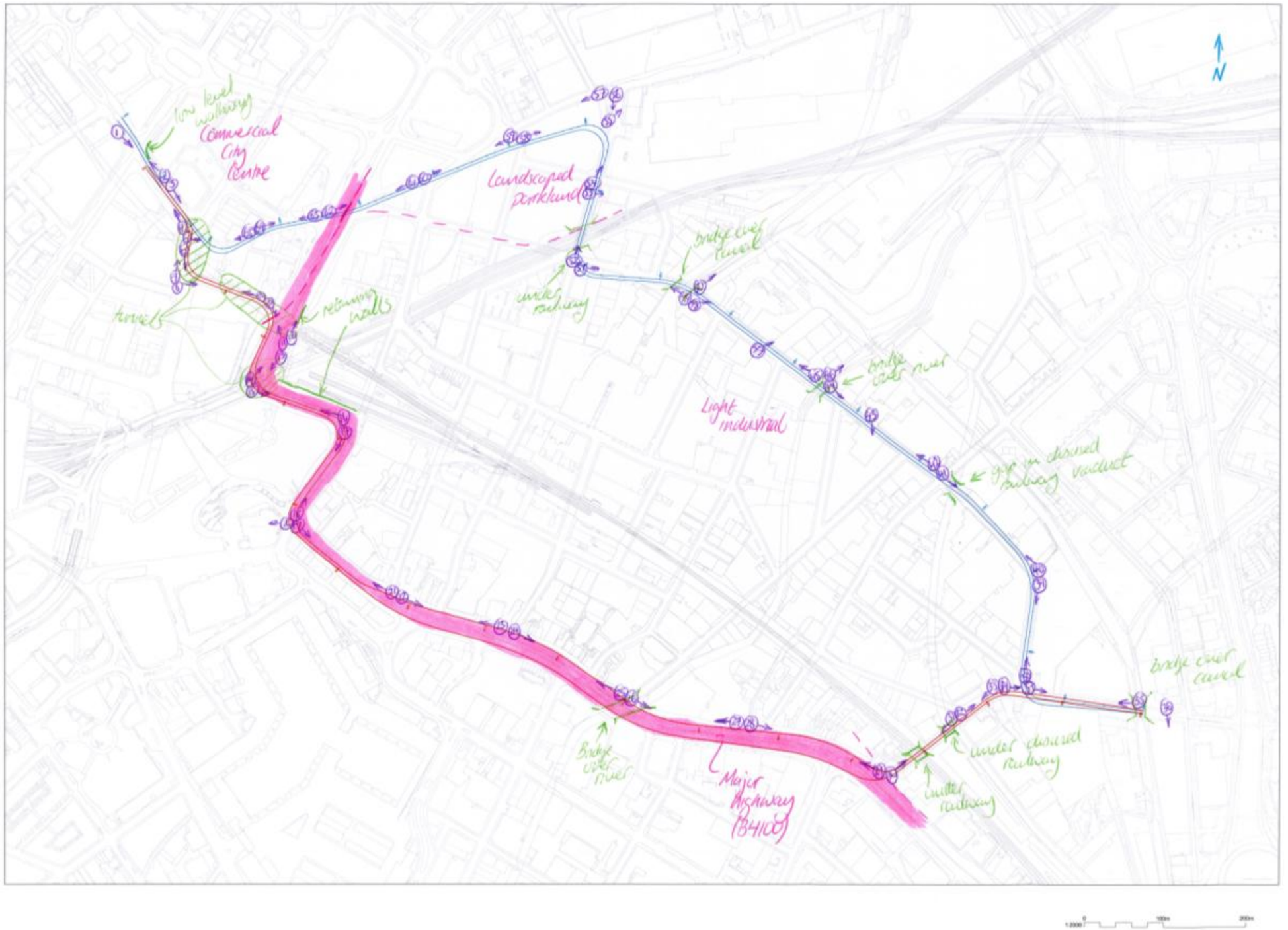
Figure A-1: Route alignment for all three Route Options



Appendix B. Site Walkover

B.1 Option A and C Walkover Plan

Figure B-1: Site Walkover Plan for Route Option A and C



B.2 Option A and C Walkover Photographs

Photo 1: Eastern end of the site at the Bull Street/Corporation Street junction

Photo 2: View north along Lower Bull Street

Photo 3: View south along Lower Bull Street

Photo 4: View north along Lower Bull Street

Photo 5: Northern end of New Meeting Street as viewed from Lower Bull Street

Photo 6: View south along High Street

Photo 7: View north along High Street

Photo 8: View east along Carrs Lane

Photo 9: View West along Carrs Lane

Photo 10: Moor Street Queensway

Photo 11: Moor Street Queensway

Photo 12: View north along Moor Street Queensway

Photo 13: View south along Moor Street Queensway

Photo 14: View north along Moor Street Queensway

Photo 15: View east along Moor Street

Photo 16: View west along Moor Street

Photo 17: View south along Park Street

Photo 18: View north along Park Street

Photo 19: View east along Digbeth

Photo 20: St. Martins Church

Photo 21: View west along Digbeth

Photo 22: View east along Digbeth

Photo 23: View west along Digbeth

Photo 24: View east along Digbeth

Photo 25: View west along Digbeth

Photo 26: View east along High Street Deritend

Photo 27: View west along High Street Deritend

Photo 28: View east along High Street Deritend

Photo 29: View west along High Street Deritend

Photo 30: View east along Adderley Street

Photo 31: View west along Adderley Street

Photo 32: View east along Adderley Street

Photo 33: View west along Adderley Street

Photo 34: View east along Adderley Street

Photo 35: View west along Adderley Street

Photo 36: Eastern end of the site on Adderley Street

Photo 37: View east along Adderley Street

Photo 38: View north along Liverpool Street

Photo 39: View south along Liverpool Street

Photo 40: View west along Liverpool Street

Photo 41: View east along Liverpool Street

Photo 42: View west along Fazeley Street

Photo 43: Former chapel on Fazeley Street

Photo 44: View west along Fazeley Street

Photo 45: View west along Fazeley Street

Photo 46: The River Rea

Photo 47: Industrial building on Fazeley Street

Photo 48: View east along Fazeley Street

Photo 49: View west along Fazeley Street

Photo 50: Birmingham and Warwick Canal (Digbeth branch)

Photo 51: View east along Fazeley Street

Photo 52: View north along New Canal Street

Photo 53: The Eagle and Tun Inn on New Canal Street

Photo 54: View north along New Canal Street

Photo 55: Former Curzon Street Station building

Photo 56: View south along New Canal Street

Photo 57: View west along the former route of Curzon Street

Photo 58: View east along the former route of Curzon Street

Photo 59: View west along Albert Street

Photo 60: View east along Albert Street

Photo 61: View west along former route of Albert Street

Photo 62: Moor Street Queensway

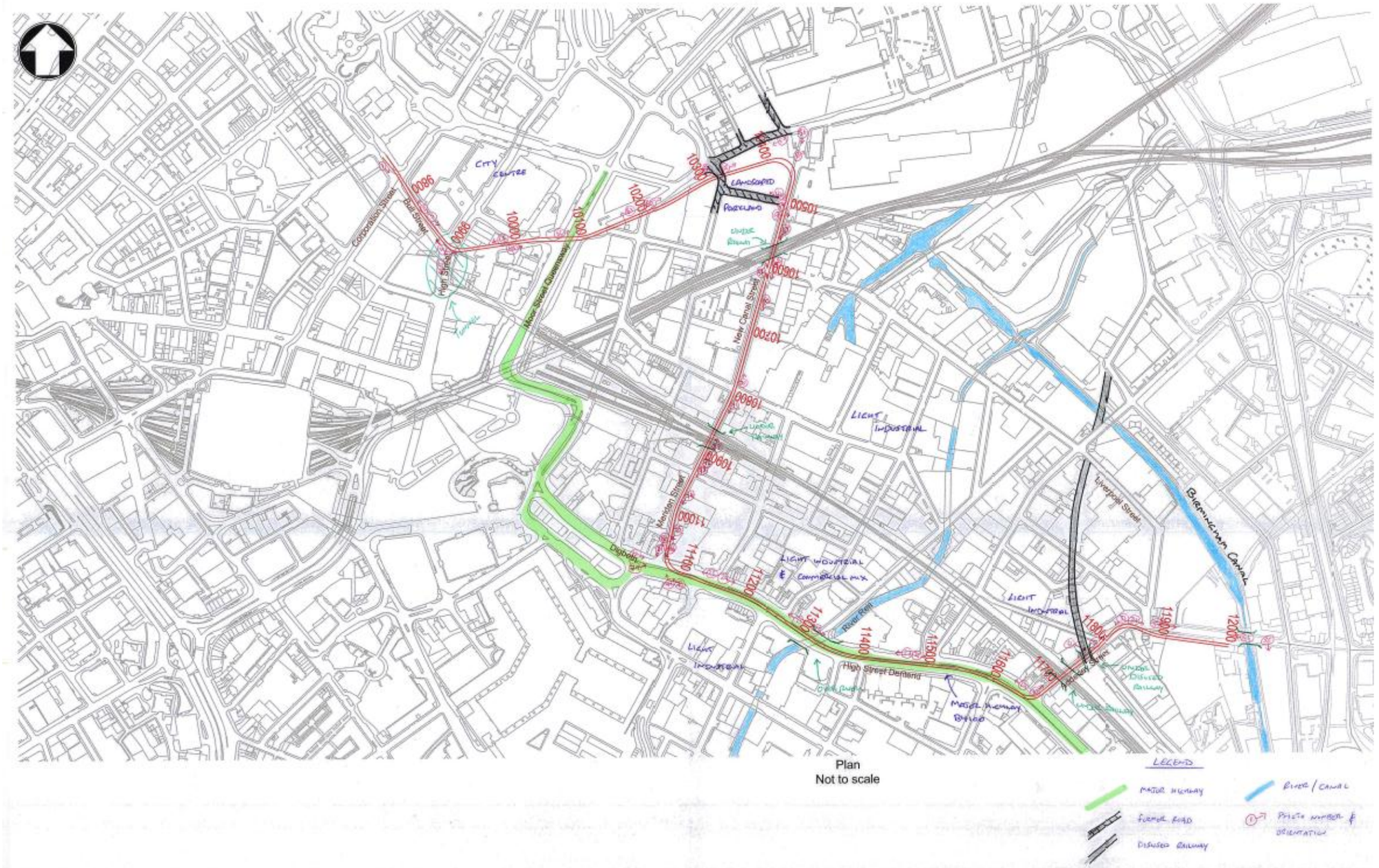
Photo 63: View west along Albert Street

Photo 64: View east along Albert Street

Photo 65: View west along New Meeting Street

B.3 Option B Walkover Plan

Figure B-2: Site Walkover Plan for Route Option B



B.4 Option B Walkover Photographs

The western section of Option A and the eastern half of Option C cover the majority of the Option B tram route. Therefore in order to avoid repetition, the following walkover photographs from section B.2 are applicable to Option B: Photo 1; 2; 3; 4; 5; 6; 22; 23; 24; 25; 26; 27; 28; 29; 30; 31; 32; 33; 34; 35; 36; 37; 52; 53; 54; 55; 56; 57; 58; 59; 60; 61; 62; 63; 64; 65.

The following photographs are in addition to the photographs contained with Section B.2 and are applicable to Option B tram route:

Photo 66: View west along former route of Banbury Street

Photo 67: View south along New Canal Street towards New St railway line

Photo 68: New Canal Street and Fazeley Street junction

Photo 69: View south along New Canal Street

Photo 70: View north along New Canal Street

Photo 71: View south along New Canal Street, at Bordesley Street junction

Photo 72: View north of Moor St railway line viaduct

Photo 73: View south of Meriden Street and Coventry Street junction

Photo 74: View south along Meriden Street

Photo 75: View south along Meriden Street

Photo 76: View south of Meriden Street and B4100 junction

Photo 77: View north of B4100 and Meriden Street junction

Photo 78: View west towards Digbeth

Photo 79: View east of B4100 and Meriden Street junction

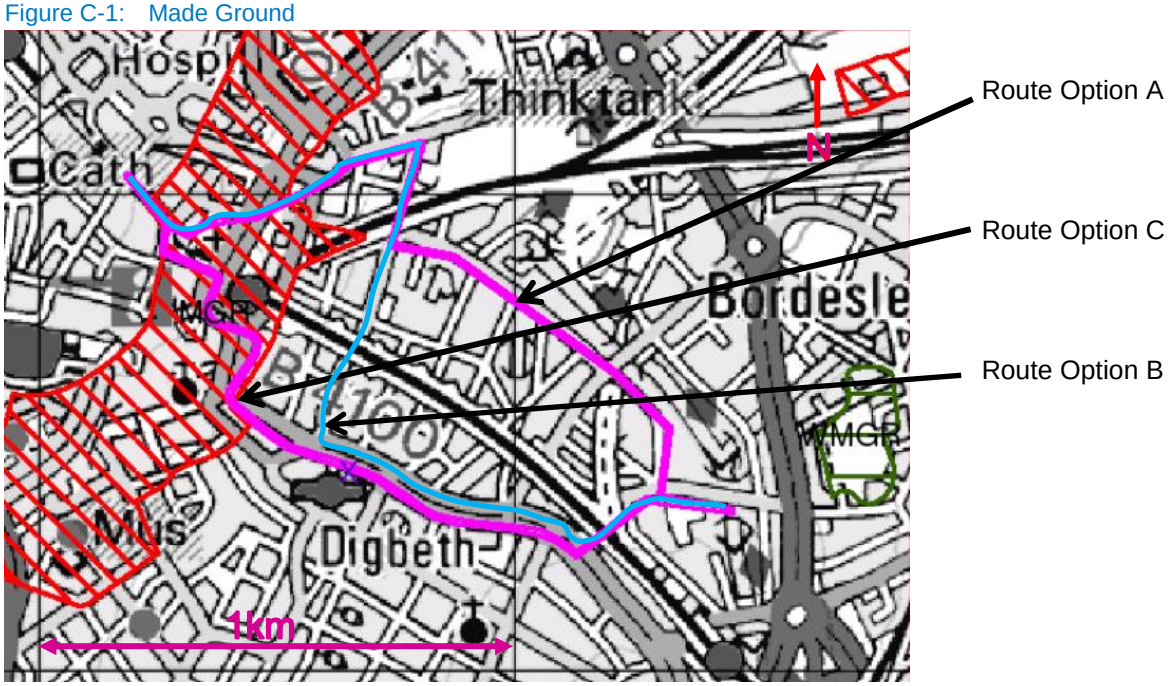
Photo 80: Suspected basements under existing footway (facing south)

Photo 81: Suspected basements under existing footway (facing south)

Appendix C. Geological Records

C.1 Geological mapping

Figure C-1: Made Ground



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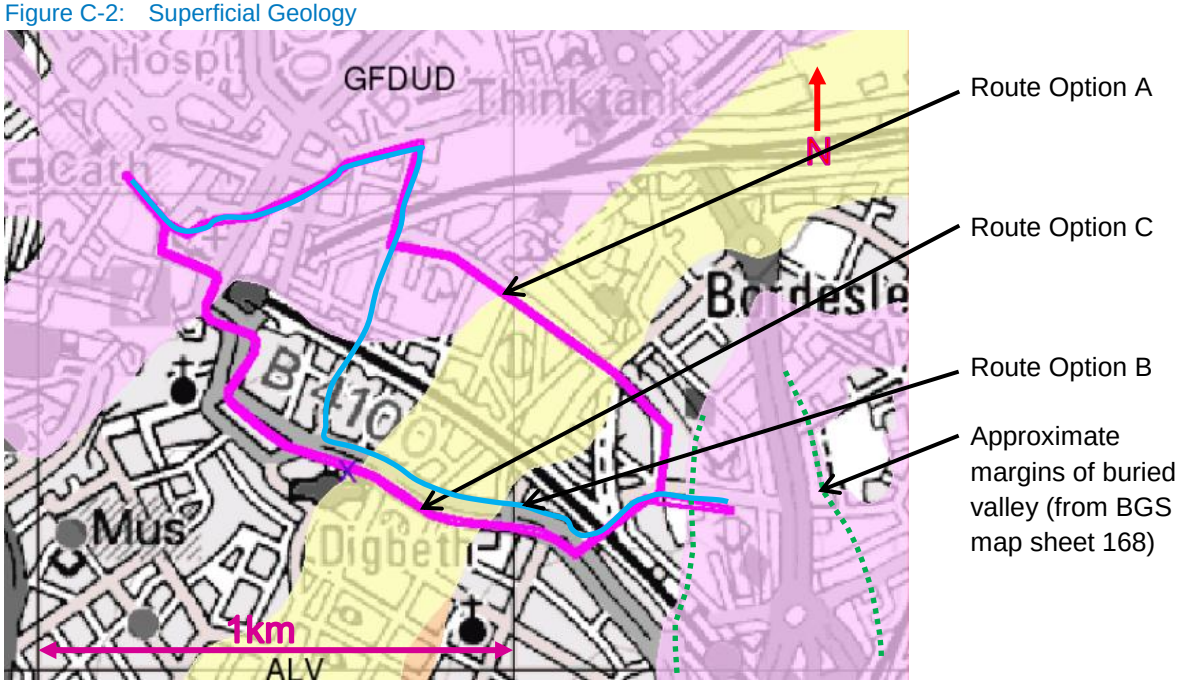
Key

Hatch	Code	Material
	MGR	Made Ground
	WMGR	Infilled Ground

Figure C-2: Superficial Geology

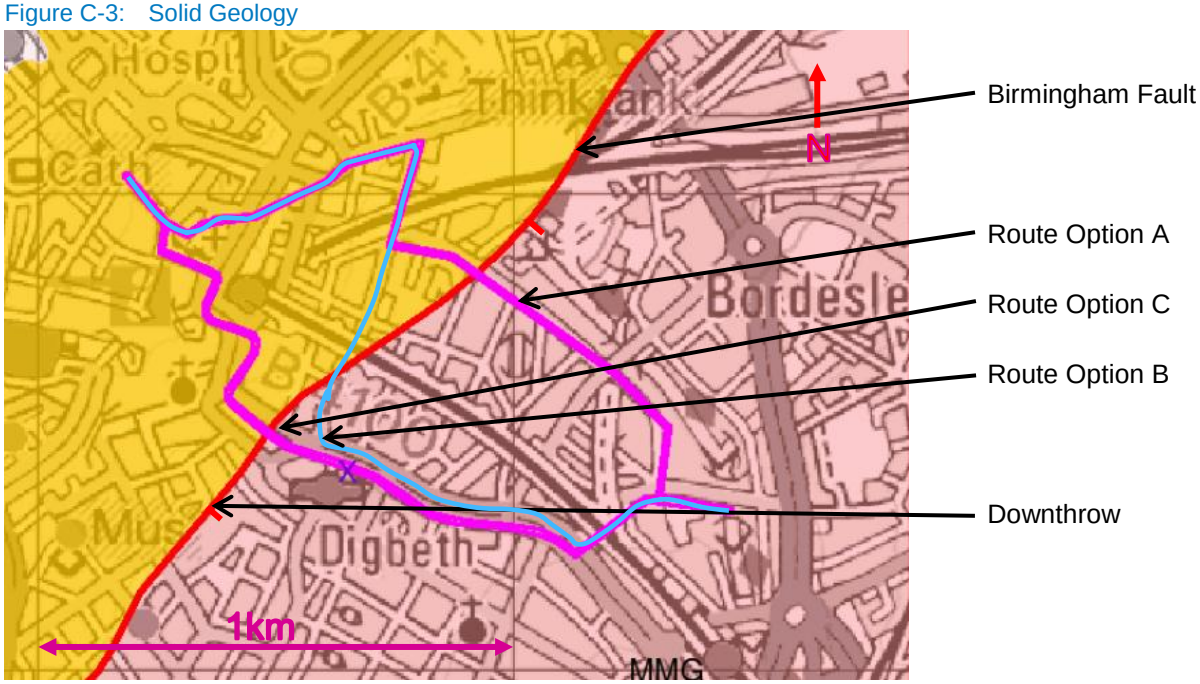


Source: Envirocheck Report, © Crown Copyright. All rights reserved License Number 100022432

Key

Hatch	Code	Deposit
	GFDUD & GFDMP	Glaciofluvial Deposits
	ALV	Alluvium
	RTD1	River Terrace Deposits

Figure C-3: Solid Geology



Key

Hatch	Code	Deposit
	BMS	Bromsgrove Sandstone Formation
	MMG	Mercia Mudstone Group
	-	Fault

C.2 Geological long sections along the Route Options based on selected historical BGS borehole records.

Figure C-4: Geological Long Section for Route Option A

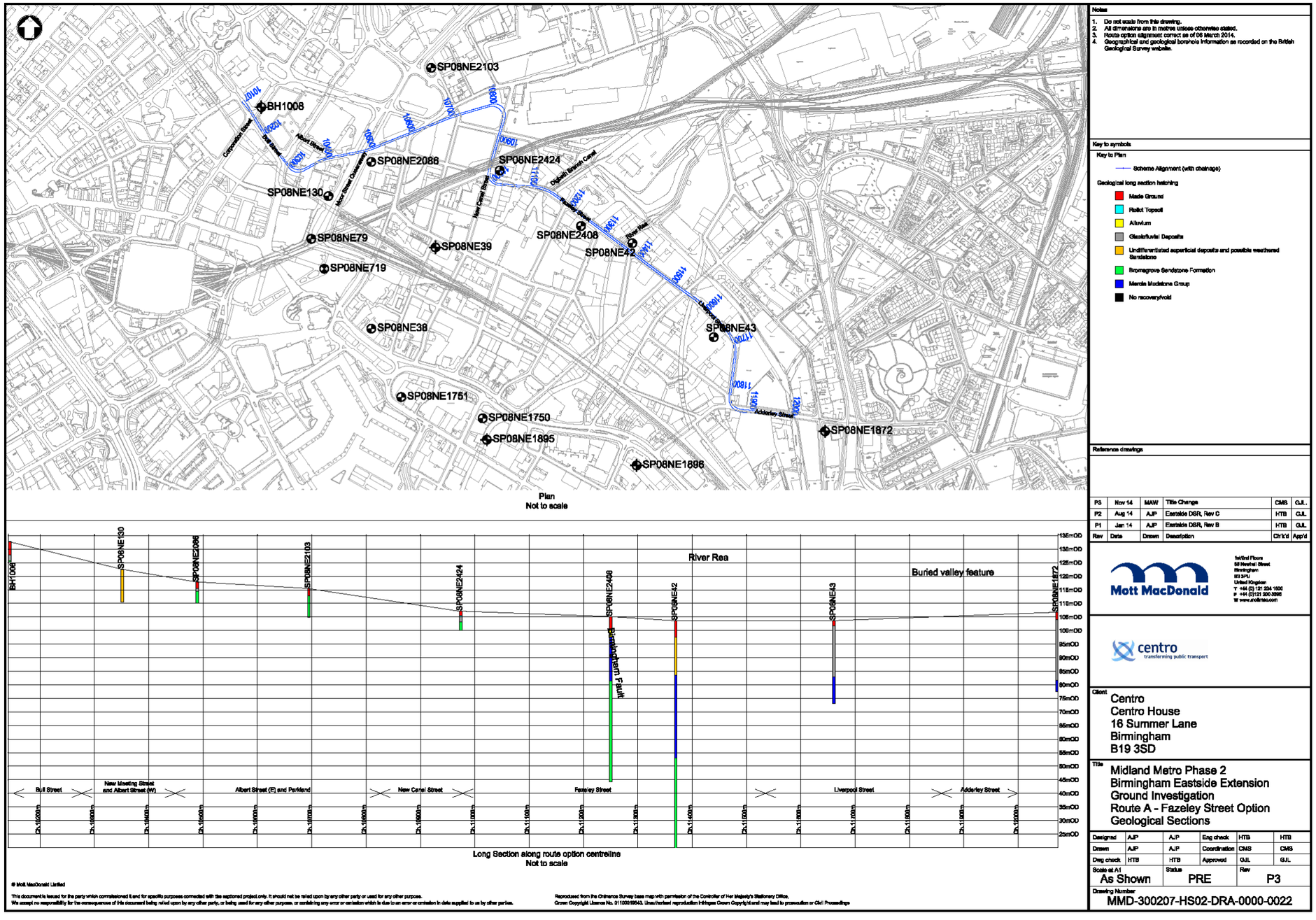


Figure C-5: Geological Long Section for Route Option C

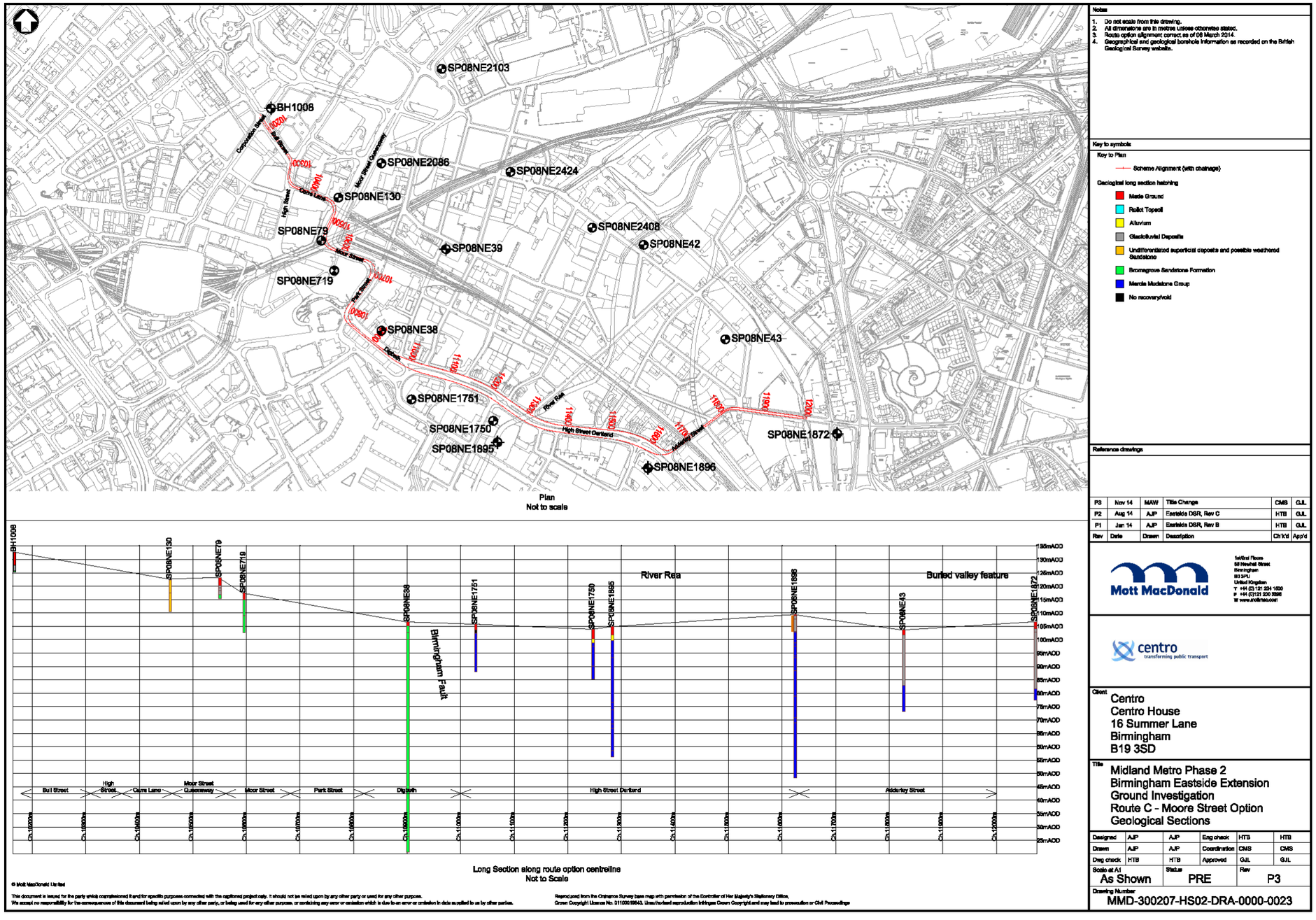
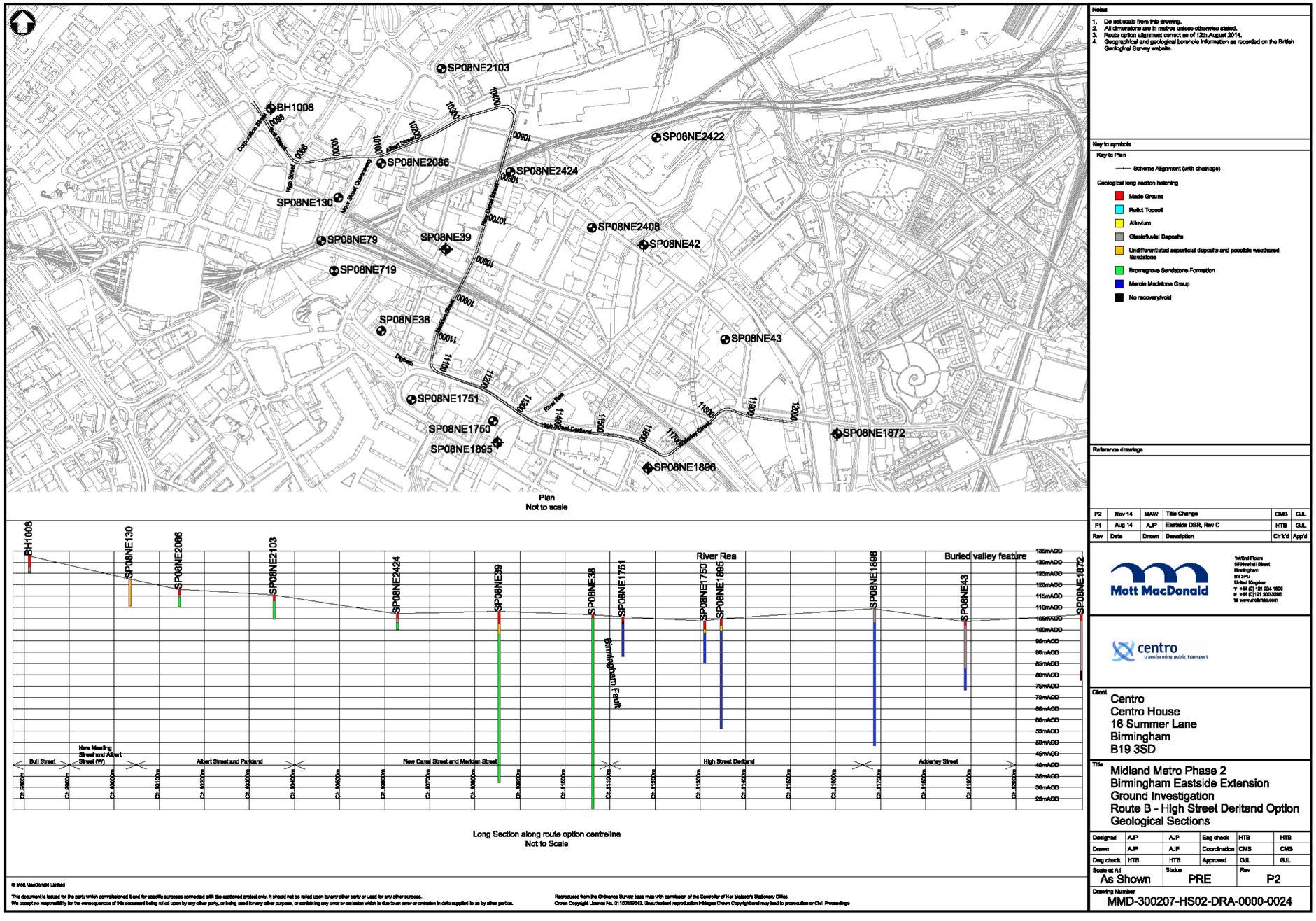


Figure C-6: Geological Long Section for Route Option B



Appendix D. Geotechnical Parameters

The following geotechnical parameter sets are duplicated from the Ground Investigation Report for Centenary Square Extension[xii]; they should only be taken as indications of likely geotechnical parameters for on-site deposits. Where geotechnical parameters vary with depth reference should be made to the reference document in which geotechnical parameter plots may be found.

Figure D-1: Geotechnical parameters identified on the Midland Metro Centenary Square Extension Project

Table 5.3: Preliminary geotechnical parameters for Granular Glaciofluvial deposits

Parameter		Symbol	Value	Unit	Notes
Bulk Unit weight		γ_{bulk}	1.9	Mg/m^3	Based on BS8002, Table 1[xii]
Shear strength - Effective Stress	Angle of shearing resistance	ϕ'	39	Deg.	See Chart D.1
	Cohesion	c'	-	kPa	
Shear strength - Total Stress		c_u	-	kPa	
Stiffness		E_s	100 to 200	MPa	Based on table 2-8 in Bowles[xi] Assuming dense sand and gravel

Table 5.4: Preliminary geotechnical parameters for Cohesive Glaciofluvial deposits

Parameter		Symbol	Value	Unit	Notes
Bulk Unit weight		γ_{bulk}	1.9	Mg/m^3	Based on BS8002, Table 1[xii]
Shear strength - Effective Stress	Angle of shearing resistance	ϕ'	28	Deg.	See Chart D.1
	Cohesion	c'	0	kPa	Assumed
Shear strength - Total Stress		c_u	Varies	kPa	See Chart E.2
Stiffness		E_u	Varies	MPa	See Chart E.4

Table 5.5: Preliminary geotechnical parameters for Granular Bromsgrove Sandstone Formation (weathered)

Parameter		Symbol	Value	Unit	Notes
Bulk Unit weight		γ_{bulk}	1.9	Mg/m^3	Based on BS8002, Table 1[xii]
Shear strength - Effective Stress	Angle of shearing resistance	ϕ'	39	Deg.	See Chart D.1
	Cohesion	c'	-	kPa	
Shear strength - Total Stress		c_u	-	kPa	
Stiffness		E_s	50-200	MPa	Based on table 2-8 in Bowles[xi] Assuming dense sand or sand and gravel

Table 5.6: Preliminary geotechnical parameters for Cohesive Bromsgrove Sandstone Formation (weathered)

Parameter		Symbol	Value	Unit	Notes
Bulk Unit weight		γ_{bulk}	2.0	Mg/m³	Based on BS8002, Table 1[xii]
Shear strength - Effective Stress	Angle of shearing resistance	ϕ'	28	Deg.	See Chart D.1
	Cohesion	c'	0	kPa	Assumed
Shear strength - Total Stress		c_u	Varies	kPa	See Chart E.2
Stiffness		E_u	varies	MPa	See Chart E.4

Table 5.7: Preliminary geotechnical parameters for Bromsgrove Sandstone Formation (Sandstone)

Parameter	Symbol	Value	Unit	Notes
Bulk Unit weight	γ_{bulk}	1.9	Mg/m³	From UCS testing results
UCS	σ_c	Varies	MPa	See Chart E.3
Stiffness	E_m	Varies	GPa	See Chart E.5

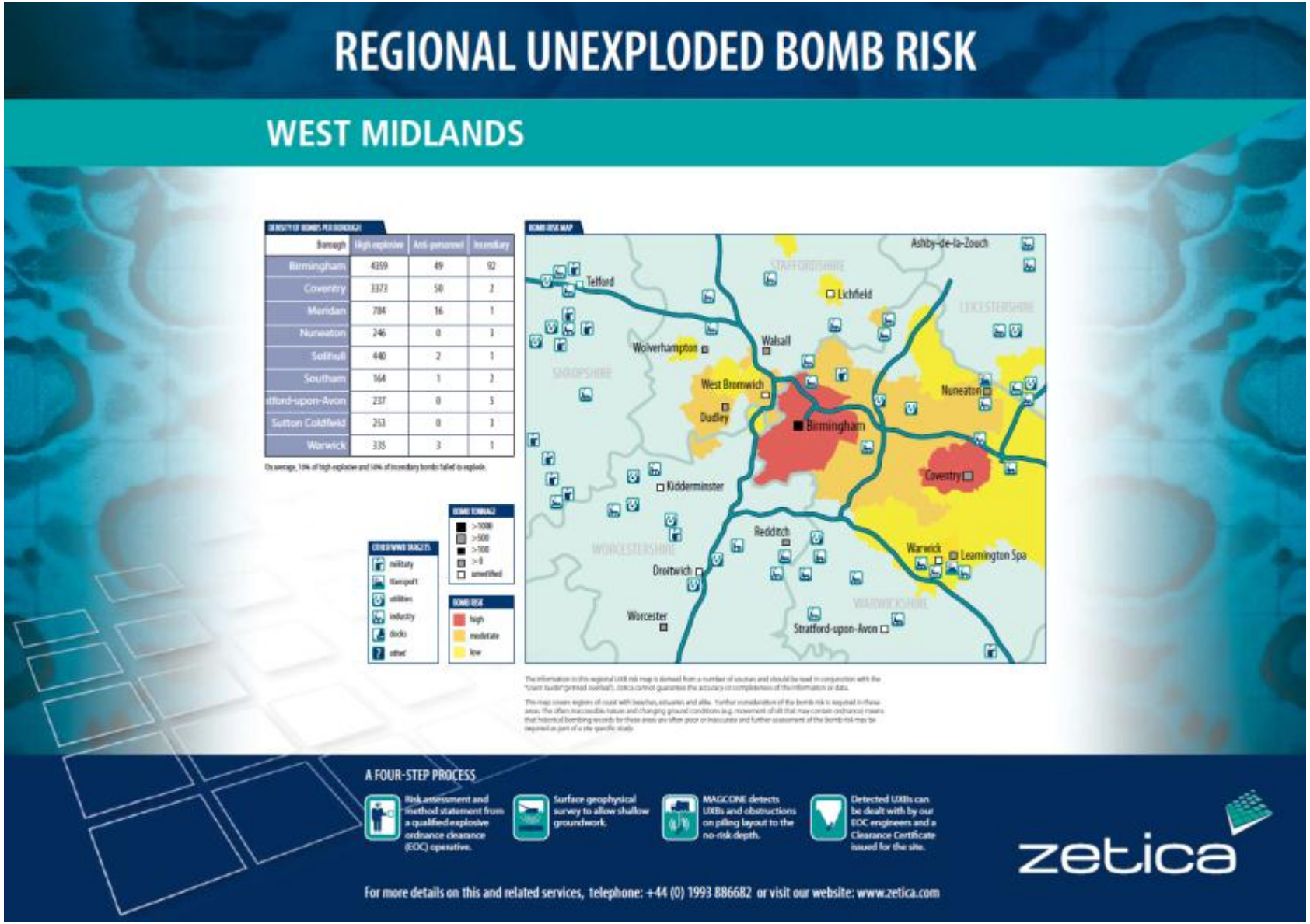
Table 5.8: Preliminary geotechnical parameters for Bromsgrove Sandstone Formation (Mudstone)

Parameter	Symbol	Value	Unit	Notes
Bulk Unit weight	γ_{bulk}	2.0	Mg/m³	Assumed
UCS		Varies	MPa	See Chart E.3
Stiffness	E_m	Varies	GPa	See Chart E.5

Source: Mott MacDonald GIR for Centenary Square Extension

Appendix E. Zetica UXO risk mapping

Figure E-1: Zetica UXO Risk Mapping for the West Midlands



BOMB MAP USERS' GUIDE

Sources of information and explanation of bomb risk

Why?
Unexploded bombs (UXB) still present a risk to construction projects long after the end of the Second World War (WWII). UXBs often entered the ground unnoticed at high velocity and penetrated to a depth of several metres. Here they remain – vulnerable to disturbances from construction work. Beyond the depth of shallow excavation work, the greatest risk is to piling, drilling and probing crews. A piling rig could repeatedly hit a UXBs with considerable force before the crew realises an obstruction has been impacted. It could then be up to 72 hours before the detonator activates.

Who?
The responsibility for avoiding UXB risk usually lies with construction companies or house builders particularly those who are redeveloping urban sites. In addition, project engineering or environmental consultants are expected to advise their clients of a site's history. Other interested parties include those organisations whose employees are physically at most risk from intrusive works, normally piling companies, drillers or probing operators.

How?
UXB risk should be assessed for every site, but especially those in known heavily bombed areas or those situated near war-time strategic installations that were priority targets for enemy aircraft, for example, airfields. Zetica's regional bomb risk map is therefore a first point of reference from which the relative, potential abundance of UXBs can be judged. Consultants then advise their clients that an ordnance-risk desk study is required, which they may obtain from external sources. Construction companies or house builders who assess their own risk could choose to come direct to Zetica.

When?
Do not wait for the piling or drilling company to be on site before thinking about UXB risk – it will inevitably cause delays and higher costs. Request the regional bomb risk map from Zetica as soon as a site is being considered, and then use it to help you or your clients to decide if an ordnance-risk desk study is required.

Where?
Maps can be obtained for any county in England, Scotland, Wales or Northern Ireland – or for any London borough. They can help determine the areas that were most heavily bombed – but no part of the country should be considered 100% safe from UXB risk. Even remote rural areas can have a high risk if, for example, they were locations for decoy airfields or beacons that were lit to fool enemy pilots into thinking they had located a burning city that had been successfully hit by others in the raid.

How to use this regional map
This map is designed to give you an indication of the potential risk from UXBs in your area. If you are conducting work that involves excavation, piling or other disturbance of the ground, then you should use the map to identify the category of risk for your site.

The risk boundaries are a guide, compiled from data based on the political areas for which records are held; being just outside a high-risk area does not mean there is no UXB risk. You should use the map to assist in your decision of whether to investigate the UXB risk further.

Information on the regional risk remaining from UXBs in the UK
Zetica has built the largest UXB database of its kind in the UK. It includes a unique digital library of bomb census data, and maps showing key strategic points and bombing densities from the First and Second World Wars. The main sources of information include records from central government (Public Records Office), the Ministry of Defence, and the German Luftwaffe.

Using information from this database, Zetica has published maps of UXB risk on a regional, county and borough scale. The maps indicate relative degrees of UXB risk based on available records for bombing densities and known targeted areas for regions within the UK. The risk is broken down into individual boroughs, towns or cities. The data are based on the historical boroughs and are then overlaid onto the modern map. It is important to note that more-detailed research may be required for individual sites, particularly where proximity to a potential WWII target means the local risk may be higher.

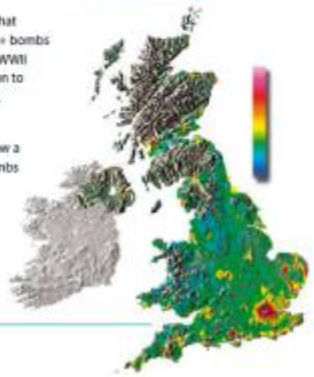
High risk
Areas designated as high risk are those that show a high density of bombing hits (50+ bombs per 1000 acres) and abundant potential WWII targets. In high-risk regions, further action to mitigate UXB risk is considered essential.

Moderate risk
Moderate-risk regions are those that show a bomb density of between 11 and 50 bombs per 1000 acres and that may contain potential WWII targets. Action to mitigate the risk is considered essential, albeit more likely that a reduced scope of work is required compared with that needed for high-risk regions.

Low risk
Low-risk regions are those with a bombing density of up to 10 bombs per 1000 acres. These areas are considered to have a significant but low UXB risk. In general, further action to mitigate the risk is considered prudent, although not essential. Care is required when assessing the risk for specific sites where the risk may be higher because of local wartime activity.

Other WWII targets
Other regions with the risk of UXBs are key strategic points as defined by the government during WWII as representing potential enemy targets. Where these exist outside areas mapped as high, moderate or low risk, a site-specific assessment of the UXB risk may be required.

Relative UXB risk across UK



What to do if…
…you have a site that has a potential UXB risk
In the absence of current legislation requiring you to address the risk from UXBs, your responsibilities under health and safety legislation and regulations such as construction design and management require that you address all identified risks. The first stage is to request further advice from a professional adviser such as Zetica, or to gain more site-specific information by commissioning an ordnance-risk desk study. Then a strategy to deal with the risk can be established that is tailored to your proposed work.

…you find a suspect item or require advice
If during site works you find a suspect (ordnance-related) item, it is very important that you do not touch or move it (even if it has already been moved by an excavator). If it is clearly ordnance related, then dial 999 and ask for the police. Ensure that the area around the item is kept as clear as possible without placing yourself at risk. If you are unsure and do not wish to cause undue alarm, or you just require some advice, then you can call Zetica. We have experienced qualified UXB specialists on hand who can offer support and advice during any site works.

More-detailed procedures should be established in advance if you are in an area where the risk of finding a UXB is shown to be significant (moderate to high).

Site-specific desktop studies
Zetica is able to provide high-quality, site-specific UXB risk information for any residential, industrial or commercial property in the UK. These desktop studies provide details of the bombing density within an area and for the site itself, in order to indicate the risks of UXBs still being present. A risk assessment is provided to facilitate informed decision making on whether any further risk mitigation measures are required.

For more details on this and related services, telephone: +44 (0) 1993 886682 or visit our website: www.zetica.com

Source: Zetica Limited

Appendix F. Contaminated Land Risk Assessment Methodology

The following Contaminated Land Risk Assessment methodology is based on CIRIA C552 (2001) *Contaminated Land Risk Assessment – A Guide to Good Practice*, in order to quantify potential risk via **risk estimation** and **risk evaluation**, which can be adopted at the Phase I (Desk Study) stage. This will then determine an overall risk category which can be used to identify potential investigation or remedial actions. This methodology uses qualitative descriptors and therefore is a qualitative approach based on desk information. The risk assessment should be refined following receipt of ground investigation data.

The methodology requires the classification of:

- the magnitude of the **consequence** (severity) of a risk occurring, and
- the magnitude of the **probability** (likelihood) of a risk occurring.

The potential consequences of contamination risks occurring at this Site are classified in accordance with Table 7-1 below, which is adapted from the CIRIA guidance.

Table 7-1: Classification of Consequence

Classification	Definition of Consequence
Severe	Short-term (acute) risks to human health. Short-term risk of pollution of sensitive water resource or ecosystem. Catastrophic damage to crops/buildings/property/infrastructure, including off-site soils.
Medium	Medium/long-term (chronic) risks to human health. Medium/long-term risk of pollution of sensitive water resource or ecosystem. Significant damage to crops/buildings/property/infrastructure (on or off-site). Contamination of off-site soils.
Mild	Easily preventable, permanent health effects on humans. Pollution of non-sensitive water resources. Localised damage to crops/buildings/property/infrastructure (on or off-site).
Minor	Easily preventable, non-permanent health effects on humans, or no effects. Minor, low-level and localised contamination of on-site soils. Easily repairable damage to crops/buildings/property/infrastructure.

The probability of contamination risks occurring at this Site will be classified in accordance with Table 7-2 below which is also adapted from the CIRIA guidance. Note that for each category, it is assumed that a pollution linkage exists. Where a pollution linkage does not exist, the likelihood is zero, as is the risk.

Table 7-2: Classification of Probability

Classification	Definition of Probability
High Likelihood	Circumstances are such that an event appears very likely in the short-term or almost inevitable in the long-term; or there is already evidence that such an event has occurred.
Likely	Circumstances are such that such an event is not inevitable, but is possible in the short-term and is likely over the long-term.
Low Likelihood	Circumstances are such that it is by no means certain that an event would occur even over a longer period, and it is less likely in the short-term.
Unlikely	Circumstances are such that it is improbable that an event would occur even in the very long-term.

For each possible pollution linkage (source-pathway-receptor) identified, the potential risk can be evaluated based upon the following probability x consequence matrix.

Table 7-3: Overall Contamination Risk Matrix

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability	**High likelihood**	Very high risk	High risk	Moderate risk	Low risk
	Likely	High risk	Moderate risk	Moderate risk	Low risk
	Low likelihood	Moderate risk	Moderate risk	Low risk	Very low risk
	Unlikely	Low risk	Low risk	Very low risk	Very low risk

Based upon this, CIRIA C552 presents definitions of the risk categories, together with the investigatory and remedial actions that are likely to be necessary in each case, as in Table 7-4. These risk categories apply to each pollutant linkage, not simply to each hazard or receptor.

Table 7-4: Definition of Risk Categories and Likely Actions Required

Risk Category	Definition and likely actions required
Very high	Severe harm to a defined receptor is very likely, or has already occurred. The risk is likely to result in a substantial liability. Urgent investigation (if not already undertaken) is likely to be required. Urgent remediation is likely to be required.
High	Harm to a defined receptor is likely. The risk, if realised, may result in a substantial liability. Urgent investigation (if not already undertaken) is likely to be required. Remediation is likely to be required in the long term, possibly sooner.
Moderate	Harm to a defined receptor is possible, but severe harm is unlikely. Investigation is likely to be required to clarify the level of potential liability and risk. Some remediation may be required in the longer term.
Low	Harm to a defined receptor is possible, but is likely to be mild at worst. Liabilities could theoretically arise, but are unlikely. Further investigation is not required at this stage. Remediation is unlikely to be required.
Very low	Harm to a defined receptor is unlikely, and would be minor at worst. No liabilities are likely to arise. Further investigation is not required at this stage. Remediation is very unlikely to be required.

Appendix G. References

[i] British Geological Survey online mapping; www.bgs.ac.uk/geoindex
[ii] Powell JH, Glover BW and Waters CN (2000). Geology of the Birmingham Area, Memoir for 1:50,000 Geological Sheet 168 (England and Wales).
[iii] British Geological Survey (1996), Solid and Drift 1:50,000 Geology map sheet 168, Birmingham.
[iv] Landmark Envirocheck report number 53411132_1, 18th February 2014.
[v] Landmark Envirocheck report number 59640998_1, 26th August 2014.
[vi] British Geological Survey online borehole scans; http://www.bgs.ac.uk/data/boreholescans/
[vii] Environment Agency interactive mapping; http://www.environment-agency.gov.uk/homeandleisure/37793.aspx
[viii] Multi Agency Geographical Information for the Countryside (Magic) website; http://www.environment-agency.gov.uk/homeandleisure/37793.aspx
[ix] Archaeological Data Service website; http://archaeologydataservice.ac.uk/
[x] Geotechnics Ltd. Factual report for Ground Investigation at Midland Metro Phase 1, Birmingham City Centre Extension. September 2011. Project number PC114609.
[xi] Mott MacDonald Ltd. Desk Study Report for Midland Metro Phase 2 – High Speed Rail Link, January 2013. Report number: 300207-HS02-DOC-002-RevA. PiMs ref: 1521134848.
[xii] Mott MacDonald Ltd. Ground Investigation Report for Midland Metro Phase 2 – Centenary Square Extension Rev B, February 2014. Report number: 300207-CS12-DOC-0000-0003-Revb. PiMs ref: 1547970240.
[xiii] CIRIA Report C570, Engingeering in Mercia Mudstone, 2001.
[xiv] The Geological Society, Engineering Geology Special Publication No. 21, Clay Materials Used in Construction, Edited by GM Reeves, I Simms and J Cripps, 2006
[xv] Department of the Environmental Food and Rural Affairs (2012): *"Environmental Protection Act 1990: Part 2A, Contaminated Land Statutory Guidance",* April 2012.
[xvi] Environment Agency (2008): "*Human Health Toxicological Assessment of Contaminants in Soil*", Report ref. SC050021/SR2
[xvii] Environment Agency (2008): "*Updated technical background to the CLEA Model*", Report ref. SC050021/SR3
[xviii] British Standards Institution (2011): "*Investigation of Potentially Contaminated Sites",* BS10175:2011
[xix] Environment Agency (2013): "*Groundwater Protection: Principles and Practice*", Ref. GP3. August 2013 Version 1.1.
[xx] Rudland et al. (2001): "*Contaminated Land Risk Assessment: A Guide to good Practice*", CIRIA Report C552.
[xxi] Department for Communities and Local Government (2012): "*National Planning Policy Framework*"
[xxii] Birmingham City Council. (2009). *"Guidance on Development of Contaminated Land"*.