MOTT MACDONALD

Western Link

Geo-environmental Phase 1 Desk Study Report

25 April 2017

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1 Introduction

1.1 Introduction

Mott MacDonald Limited have been commissioned to provide an outline business case submission to the DfT for a western link highway connection between the A56 and A57 to the south-west of Warrington town centre. This report seeks to inform the Stage 1 Outline Business Case.

1.2 Scheme description

Warrington Borough Council have received funding from the Department for Transport (DfT) to develop an Outline Business Case (OBC) for the Western Link Scheme (henceforth known as "The Scheme". The overall aims of The Scheme are to:

- address the steady rise in congestion levels that are a result of Warrington's recent rapid economic growth, particularly in the town centre; and
- open up new development land to support continued economic investment in central Warrington.

Historically, the River Mersey, Manchester Ship Canal and West Coast Main Line (WCML) railway have acted as barriers that create traffic 'pinch points' on the transfer network. Consequently, traffic between north and south Warrington must go through the town centre, leading to serious congestion problems. The Scheme is intended to address these issues, with the OBC to be presented to the DfT by the end of December 2017.

The Scheme involves the construction of a single carriageway connecting Chester Road (A56) located to the south of Warrington, to Sankey Way (A57) located to the north west of Warrington town centre.

The overall cost of The Scheme is approximately £150m.

There are several proposed route options under consideration, including high level bridge crossings and tunnelling options. Route options are shown on Figure 1 in red.

1.3 Report objectives

The purpose of this report is to provide an initial geotechnical and geo-environmental appraisal of the route options. The aims of this appraisal are to:

- collect available geotechnical and geo-environmental information;
- identify the presence or otherwise of geotechnical and geo-environmental constraints on the route options.

1.4 Methodology

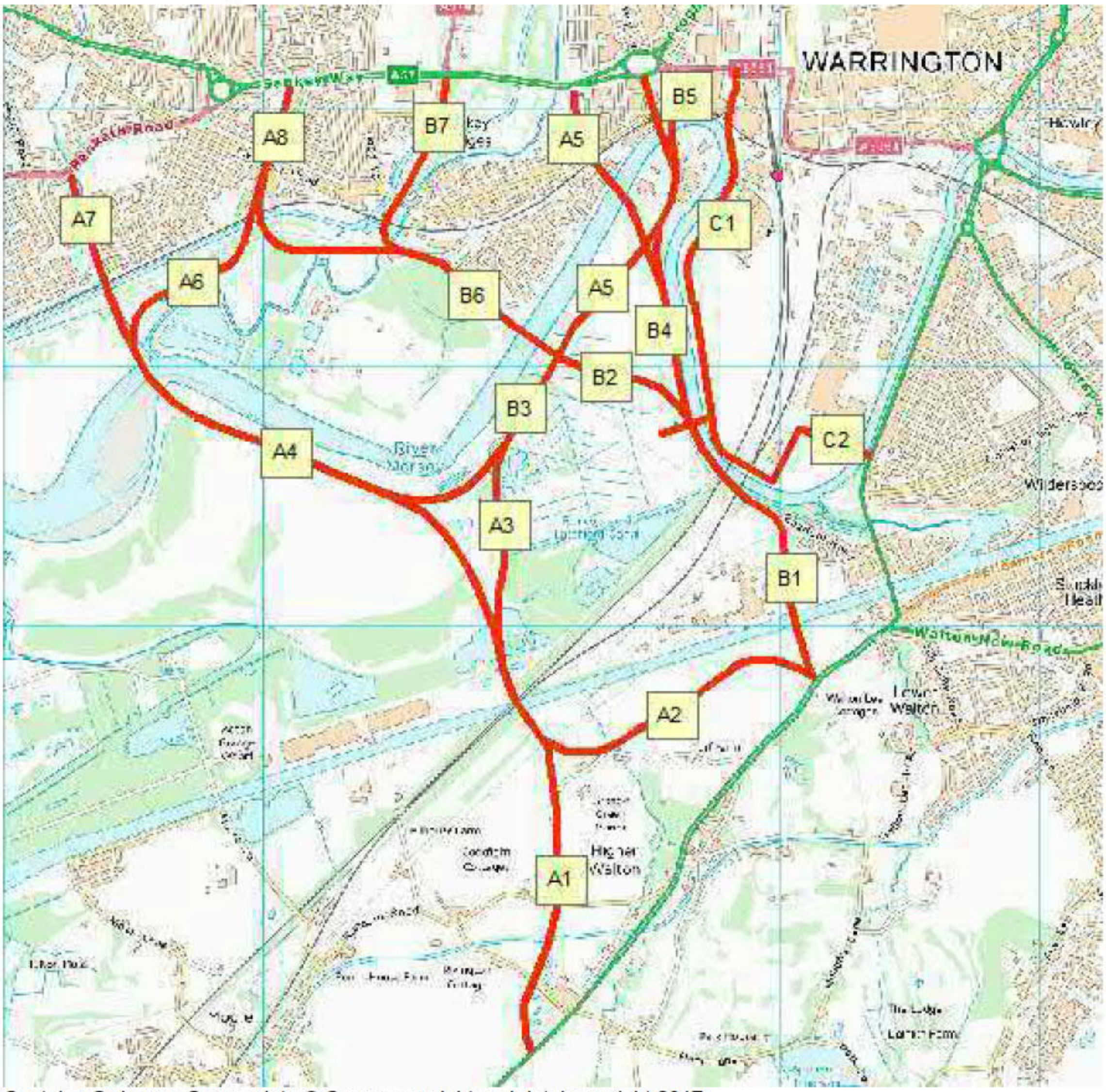
At OBC Stage 0 long-list route option stage there are multiple potential route corridors selected as identified in Figure 1, many of which share corridor segments. Route corridors are taken from MML Report 382900 02 A 7 April 2017 Western Link Warrington Transport Improvement Schemes Sift 1. For the purposes of this report, the main text will focus on a generic view of ground conditions within the study area and will seek to identify broad geotechnical and geo-environmental risks. Detailed ground condition summaries for route segments have been assessed and are presented separately in Appendix E. Nomenclature for route segments in relation to the routes is shown on Figure 1 thereby allowing assessment of detailed ground conditions per route.

1.5 Sources of information

The following sources of information were used in the preparation of this report:

- Site walkover and site walkover photographs (Appendix B)
- Landmark electronic datasets including site sensitivity data, 1:10,000 scale geological mapping, Historical Land Use Database and historical maps (Appendix C)
- British Geological Survey (BGS) Open Geoscience Borehole Scans (Appendix D)
- Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series Sheet 97, Runcorn, Drift, 1977
- Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series Sheet 97, Runcorn, Solid, 1977
- Coal Authority Interactive Map Viewer (http://mapapps2.bgs.ac.uk/coalauthority/home.html , accessed April 2017)
- Zetica Regional Unexploded Bomb Risk map for Cheshire (www.zetica.com accessed April 2017)

Figure 1: Route segment designations



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Source: MML Report 382900 02 A 7 April 2017 Western Link Warrington Transport Improvement Schemes Sift 1

2 Geoenvironmental overview

2.1 Study area

The combined length of the route option corridors is 16.2 km. The total study area, based on a 500m buffer either side of the route options, comprises 1059 hectares. The study area is detailed on the drawings included in Appendix C of this report and is centred on National Grid coordinates E35900 N386700.

2.2 Site description and topography

The study area and principal features are shown on Western Link Geotechnical Constraints plan WL-MMD-07-ZZ-GS-N-0003 and Western Link Geo-environmental Constraints plan WL-MMD-07-ZZ-GS-N-0004 as detailed in Figure C1 (Appendix C). From review of LIDAR data, the study area can be divided into three broad terrains. These are delineated on Figure A.1 as follows: (1) Between the A56 and the Manchester Ship Canal (MSC) the area comprises predominantly arable farmland and is traversed by the Network Rail West Coast Mainline and Chester Line carried on embankment to the high-level Acton Grange bridge crossing over the MSC. Across this area the ground surface slopes gently northwards from a high of 37m AOD at the junction with Chester Road (A56) descending towards the MSC whose banks are at approximately 8m AOD. (2) The area north of the MSC and the River Mersey comprises the low-lying ground of the River Mersey floodplain. Through the study area the terrain has been utilised as dredging beds for the MSC and more recently as Arpley Landfill Site, which is still active, hence ground level has been locally raised from historic levels of 3–5m AOD to typically 10–15m AOD, rising to highs of 35m AOD at Arpley Landfill Site. This terrain also has the disused Latchford Canal and several nature reserves. Water level at the River Mersey lies at approximately 3m AOD but is tidal. (3) North of the Mersey the original floodplain extended to the boundary with the St Helen's Canal and Sankey Brook, before it was raised to typically 10–15m AOD with extensive residential and urban development north of the St Helen's Canal. The original floodplain area has been locally raised and supports a major sewage works.

2.3 Geology

2.3.1 Made Ground

Geological mapping does not show the presence of Made Ground within the study area. However, Made Ground is anticipated within the study area associated with highway construction and as a result of historical and current residential, industrial and commercial land use. In particular, a significant depth of Made Ground is anticipated within the central west, west and north west regions of the study area, associated with the current and historical landfill sites.

2.3.2 Superficial deposits

DiGMaPGB-10 digital geological mapping of superficial deposits is detailed on Drawing WL-MMD-07-ZZ-GS-N-0001 (Appendix C) and indicates that Mersey valley floor across the centre of the study area is underlain near surface by tidal flat deposits (marine and estuarine alluvium) or river alluvium (Sanky Brook and other tributaries of the Mersey).

A swathe of glaciofluvial sheet deposits are indicated north of the Mersey between the sewage works and the Warrington Unilever works and the A57.

Immediately south of the Manchester Ship Canal, the study area is indicated to be underlain predominantly by deposits of the Shirdley Hill Sand Formation, which comprises coastal blown sands, with localised deposits of glaciofluvial sheet deposits and glacial till. Localised outcrops of strata of Helsby Sandstone are indicated further south at Higher Walton.

With reference to the geological cross-sections that accompany BGS 1:50,000 Series Sheet 97 Runcorn Drift Edition the near-surface deposits described above can be expected to be underlain throughout most of the study area by a layer of glacial till.

The generalised description of superficial deposits given on BGS 1:50,000 Series Sheet 97 Runcorn, Drift Edition gives information on the occurrence and lithology of the above deposits as follows.

Alluvial deposits are usually less than 1m thick but are sometimes approximately 20m thick. Shirdley Hill Sand Formation deposits are also generally encountered to thicknesses of less than 1m.

Glaciofluvial sheet deposits, encountered in small isolated patches north of the Mersey, are commonly less than 1m thick but can be encountered up to 3m.

Glacial till south of the Mersey is described as commonly up to 10m thick and comprises red-brown sandy stony clay with many persistent beds of sand. In rockhead hollows there is potential for 15–40m of glacial till incorporating much sand or mudstone. North of the Mersey glacial till is described as up to 30m thick and consists of red-brown sandy stony clay with many persistent beds of sand.

2.3.3 Solid geology

With reference to BSG 1:50,000 Series Sheet 97 Runcorn Solid Edition, the study area is underlain by a gently inclined succession of solid strata from the Sherwood Sandstone Group, as detailed on Drawing 382900-WL-MMD-07-ZZ-GS-N-0002 (Appendix C), comprising the Helsby and Wilmslow Sandstone Formations. At great depth (>0.75km) the succession is underlain by Carboniferous strata.

At the Higher Walton Area and Solvay Chemical works in the SE of the study area the solid succession commences with strata of Helsby Sandstone Formation followed by the sequence described above.

Bedrock contours shown on Sheet Runcorn 97 Drift Edition indicate that either side of the River Mersey and along most of the A562/A57 corridor, bedrock elevation varies between 0 and –20m AOD, declining to a low point of approximately –25m AOD roughly coincident with the River Mersey valley. South of the Manchester Ship Canal bedrock level, where ground level is higher, bedrock elevation is indicated to be between 0 and +20m AOD.

Publicly available BGS borehole records are broadly consistent with the above contours. Boreholes in the vicinity of Manchester Ship Canal, encounter bedrock between –5 to –10m AOD as do boreholes along the A562/A57 corridor. A smaller number of boreholes taken to bedrock are available in the central study area. BGS borehole SJ58NE11 sunk near Bank Quay Station within the E-W swathe of lower bedrock elevation encountered sandstone at –51m AOD. Above bedrock superficial deposits encountered in boreholes comprises sands, slits and clays underlain by glacial till.

2.3.4 Summary of geology from BGS mapping

Across the lowest lying areas of the study area – the River Mersey and its tributaries – the surface geology consists of tidal flat deposits, typically consisting of clay, silt and sand, and alluvium of clay, silt, sand and gravel. North and south of the Mersey the near surface geology comprises the Shirdley Hill Sand Formation, a thin layer of blown sand. North of the Mersey local patches of Glaciofluvial sheet deposits, comprising sand and gravel, are in evidence. The above sequence is likely to be underlain throughout the entire study area by glacial till. At higher elevations, the water-borne and wind-blown deposits are likely to be absent and the study area can be expected to be underlain near surface by glacial till overlying bedrock. Outcrops of bedrock can be expected in the Higher Walton area. Across the remainder of the study area the bedrock geology consists of a sequence commencing with strata of the Wilmslow Sandstone Formation.

Although no Made Ground deposits are shown on BGS maps, it is evident from the site topography that the ground level at a number of locations across the study areas has been artificially raised. The Arpley Landfill site and areas of the former Gatewarth Farm landfill both feature conspicuous mounds that rise above the surrounding natural ground level. Other raised-up ground exists such as the West Coast Main Line and Chester Line embankments, and flood protection bunds.

Areas of infilled ground may also exist which are not shown on BGS maps on account of their small size or the absence of features on the ground surface by which they can be identified.

2.4 Hydrology

The principal watercourses across the study area from north to south are as follows.

- Whittle Brook
- St Helen's Canal
- Sankey Brook
- River Mersey (and unnamed tributaries)
- Runcorn and Latchford Canal (disused)
- Manchester Ship Canal (and unnamed tributaries)
- Bridgewater Canal

These features are annotated on Geo-environmental Constraints Plan WL-MMD-07-ZZ-GS-N-0004.

2.5 Hydrogeology

The Glaciofluvial sheet deposits that are locally present to the north of the study area are classified as a Principal Aquifer. The Wilmslow Sandstone Formation, which comprises the bedrock that underlies most of the study area is classified as a Principal Aquifer. The Helsby Sandstone Formation is classified as a Secondary B Aquifer. Principal Aquifers are layers of rock or soil that provide a high level of groundwater storage and may support water supply and/or river base flow on a strategic scale. Secondary B aquifers are lower permeability layers that leave only limited amounts of groundwater.

The extent of the underlying Principal Aquifer is shown on Geo-environmental Constraints Plan WL-MMD-07-ZZ-GS-N-0004.

2.6 Historic land use

2.6.1 Industrial land uses

By the mid 19th Century Warrington had become a major industrial centre. Most of the town's industry was located within the study area along the northern banks of the Mersey. It boasted iron foundries and metal mills, tool and wire making factories, textile mills and a soap works, which today is owned and operated by Unilever. Further industrial development in the south of the study area followed the opening of the Manchester Ship Canal in 1894. The northern bank of the Ship Canal hosted timber processing plants in the first half of the 20th Century, followed by chemical works, including the Solvay Chemicals plant which is still active. Rapid population growth followed Warrington's establishment as a New Town in 1968 and landfills were opened within the study area to meet the growing demand for municipal waste disposal. These include Gatewarth Farm Landfill Site and Arpley Landfill Site to the west of the study area. Arpley Landfill Site was constructed over land designated as dredging deposits grounds on historical maps. Sewage works were opened SW of the Acton Grange Viaduct in 1954 and to the west of the study area on low-lying land adjoining the northern banks the River Mersey in 1994. Both sites are still operational.

The bodies of water at Moss Wood adjoining the southern boundary of Arpley Landfill and at Acton Grange were originally the sites of sand quarries.

The extents of previous industrial land uses, as captured in Landmark's Historical Land Use Database (HLUD), and landfill sites described in Environmental Agency records are shown on the Geo-environmental constraints plan WL-MMD-07-ZZ-GS-N-0004 included in Appendix C. Historical and contemporary industrial features are annotated on the same plan.

2.6.2 UXO

The Zetica Regional Unexploded Bomb Risk map for Cheshire indicates that the study area lies within an area of low risk.

3 Ground-related constraints

3.1 Introduction

Two 1:10,000 scale constraints plans have been prepared to illustrate the location of ground hazards and subsurface receptors in relation to the Phase 1 route options. Plan WL-MMD-07-ZZ-GS-N-0003 illustrates geotechnical hazards. Geotechnical hazards are situations or events arising from the physical properties of the ground that have the potential to cause harm, including human injury, damage to property and economic loss. Plan WL-MMD-07-ZZ-GS-N-0004 shows geoenvironmental hazards and environmentally sensitive receptors. Geoenvironmental hazards are situations or events from the chemical properties of the ground, either natural or residues from industrial activities, that have the potential to cause harm to human beings, infrastructure, or the natural environment. Receptors are environmentally sensitive beneath features that could be adversely affected by the construction or operation of the route options.

3.2 Geotechnical hazards

3.2.1 Compressible ground

Areas of compressible ground comprise infilled ground such as former quarries or clay pits, other areas of infilled land or water, historic landfills or naturally compressible ground such as recent deposits such as alluvium. Former landfill sites account for some of the largest continuous areas of potentially compressible ground identified by the study. A large portion of the study area is underlain by geologically recent, unconsolidated deposits that were laid down by the Mersey and its tributaries. Such deposits may represent weak and compressible subgrades that may not be suitable for highway construction or as founding strata for highway embankments or for foundations to highway structures.

3.2.2 Infrastructure traverse of landfill

Construction of infrastructure on former landfill entails a number of hazards, including compressible ground considered above. The hazards are influenced by the form of construction and the earthwork or structure proposed. Hazards may include:

- signficant amounts of settlement due to the thickness of landfilled deposits;
- slope instability of highway cuttings in landfill;
- percolation of leachate through cutting slopes;
- low bearing capacities of foundations bearing on landfilled material;
- spontaneous combustion and subsurface fires if oxygen is introduced to landfill; and,
- creation of new contaminant linkages pilling through landfill may allow leachate to escape into aquifers or watercourses where the base liner is punctured.

The risk of settlement over landfill is dependent on a number of factors: the thickness, nature and age of the landfilled materials and the presence or absence of an engineered capping layer. Thicker landfill deposits will normally undergo greater amounts of settlement as will deposits that contain a high proportion of loose or putrescible waste.

The two largest landfill sites within the study area are Gatewarth Farm to the north of the Mersey and Arpley Landfill immediately to the south of the river. Gatewarth Farm received waste between 1968 and 1989. Deposited waste included inert, industrial, commerical, household and special waste (hazardous waste). Adjoining Gatewarth Farm Landfill was a satellite site at Liverpool Road that received inert and industrial waste beween 1976 and 1977. Arpley Landfill has received waste since 1997 and is still active. It is licensed as a co-disposal site, which means that both non-hazardous and hazardous waste have been buried together.

Hazardous waste is defined by the Environment Agency as waste that may be harmfull to human health or the environment, e.g asbestos, chemicals, healthcare waste, electrical equipment, lead-acid batteries, oily sludges and pesticides. Non-hazardous waste may include municiple waste and catering waste. Inert waste is waste that does not undergo significant physical, chemical or biological transformation such as construction or demolition waste.

3.2.3 Buried foundations and infrastructure

Parts of the study area, particularly alongside the northern banks of the Mersey have undergone extensive industrial redevelopment. Buried in these areas there may be heavy foundations, pipeworks and underground structures such as storage tanks, remaining from previous uses of the site.

3.2.4 Earthworks

Excavations into sloping ground above the ground surface as well as deep excavations and tunnelling operations generate spoil which can be potentially classified as hazardous and require off-site disposal. Generation of waste by earthworks operations is therefore a potential hazard.

Although the ground level across the study area is generally flat, the ground level has been artifically raised in a number of areas (Section 2.2), most signficantly at Arpley Landfill Site. In order to maintain appropriate vertical curvature of the proposed highway routes it is likely that areas of cut into existing ground will be required. Earthwork embankments and/or highway viaducts will also be required at the approaches to bridge crossings over the watercourses within the study area. Earthwork embankments may be required across low-lying areas of the study area (Section 2.2 Terrain 2) to mitigate flood risk to highways.

In the absence of formal vertical alignment drawings, the following expedient was adopted by this desk study to identify potential areas of cut. Using standard functionally of ArcMap GIS software a slope analysis was undertaken using open data LIDAR surveys of the region. Areas in which the existing gradient was equal to or more than 6% were aggregated to produce an approximate delineation of where earthworks cut may be required. This was superimposed on potentially contaminating land uses recorded in the Landmark Historic Landuse Database (HLUD), which resulted in a layer which identifes areas of cut in potentially contaminated land. This is shown in red on MM drawing WL-MMD-07-ZZ-GS-N-0003.

3.2.5 Groundwater control/tunnelling in soft soils

A number of highway options are routed via a tunnel beneath the existing Acton Grange Viaduct and Manchester Ship Canal (bridged by the Action Grange Viaduct). Given that tunnel passes beneath the Manchester Ship Canal, it will at its lowest elevation likely be situtated below the regional watertable level. Efforts during construction to control the watertable level by groundwater lowering could result in settlement of adjacent structures. Equally tunnelling by bored tunnel methods (particularly in soil deposits) could result in below ground volume loss that could induce settlement of nearby structures.

3.2.6 Expansive ground

Ground movement can be induced by chemical reactions. Expansion of the ground can be caused by the presence of slags from iron and steel-making processes causing damage to infrastructure. Areas of expansive ground identified on the geotechnical contraints plan comprise land uses categorised in the Historic Landuse Database as metal casting and foundries or spoil heaps of unknown constituents.

3.3 Geo-environmental hazards

3.3.1 Potentially contaminative land use

These are areas of land which potentially contain residues from industrial activities that by direct dermal contact or inhalation could harm construction workers employed in the construction of the highway or by surface runoff or infiltration could enter controlled waters.

3.3.2 Ground gas

Ground gas migrating from landfill sites or alluvial organic deposits presents an explosion hazard and, if accumulating in excavations associated with any of the routes or in service ducts, an asphyxiation or poisoning hazard. The landfills include landfills closed in the late 1980s and active landfills, which could all be producing gas emissions.

3.3.3 Invasive Species

Invasive species including Japanese Knotweed and Himalayn Balsam, which are listed on Schedule 9 of the Wildlife and Countryside Act, which makes it illegal to cause them to spread in the wild, are present within the study area. Detailed consideration of invasive species and ecology issues are outside the scope of this report.

4 Preliminary geotechnical and geo-environmental risk assessment

4.1 Introduction

Ground-related hazards – the potentially harmful situations and events that may arise from the physical or chemical properties of the ground – have been identified in Section 3.2 and Section 3.3 and illustrated on the constraints drawings presented in Appendix C. The present chapter considers these hazards in terms of the risk they may present to the route options, where risk is understood as the combination of the severity of the impact and the probability of that impact.

4.2 Geotechnical risk

Geotechnical risks are assessed for the study area as a whole in Appendix F.

4.3 Geoenviromental risk

4.3.1 Introductory

An initial Site Conceptual Model has been developed (presented in tabular form below) in line with the guidance provided in CLR11.

The Conceptual Model is developed to describe the environmental features of the study area together with the expected interaction of potential contamination sources and the wider environment.

The Conceptual Model involves undertaking a Source – Pathway – Receptor analysis of the Study area:

- 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 contaminant linkage is considered to exist whereby there is a circumstance through which environmental harm could occur and a potential environmental liability is present.

4.3.1.1 Sources

Based on a review of the current and historical land uses within the study area, the following potential sources of contamination have been identified;

- S1: Potentially contaminated Made Ground relating to current and historic land uses (dredging beds, landfills, industrial development past and present)
- S2: Potentially contaminated groundwater/landfill leachate relating to current and historic land uses
- S3: Potential for asbestos in soil associated with the former historic land uses within the study site

- S4: Potential for ground gases generated by Made Ground, notably the four recorded landfill sites within the study area (Arpley Landfill, Gatewarth Farm Landfill, Liverpool Street / Road landfill and Moore Nature Reserve former sand quarry)
- S5: Potential for off-site sources relating to historic and current land uses
- S6: Potential for off-site ground gas sources relating to historic and current land uses

4.3.1.2 Pathways

The following pathways are considered:

- P1: Direct Contact (ingestion, inhalation, dermal contact)
- P2: Vertical migration of contaminants in unsaturated zone
- P3: Vertical and horizontal migration of contaminants in the saturated zone
- P4: Vertical and lateral migration of ground gases
- P5: Direct contact with construction materials
- P6: Man-made contaminant transport pathways (services, piled foundations)

4.3.1.3 Receptors

The following receptors are considered:

- R1: Construction/Maintenance workers during construction
- R2: Controlled Waters (Principal Aquifers including Glaciofluvial sheet deposits and the Wilmslow Sandstone Formation. Secondary B Aquifer of The Helsby Sandstone Formation. Surface waters including the River Mersey, Sankey Brook, pond features associated with Moore Nature Reserve, Manchester Ship Canal, St. Helens Canal, Bridgewater Canal and connecting channel from Manchester Ship Canal to St. Helens Canal)
- R3: Future site users
- R4: Buried services and structures
- R5: Flora and Fauna
- R6: Off-site receptors (surrounding land uses and users)

4.3.2 Contaminant Linkages

Table 4.2 presents the potentially complete contaminant linkages that have been identified.

Table 4.2: Site Conceptual Model

Potential Source	Potential Receptors	Potential Pathway
S1: Potentially contaminated Made Ground relating to current and historic land uses	R1: Construction/Maintenance workers	P1: Direct contact
	R3: Future site users	P1: Direct contact
	R2: Controlled Waters	P2: Vertical migration of contaminants in unsaturated zone
		P3: Horizontal and vertical migration of contaminants within groundwater.
		P6: Man-made contaminant transport pathways (services, piled foundations)
	R5: Flora and Fauna	P1: Direct contact
S2: Potentially contaminated Groundwater relating to current and historic land uses	R4: Buried services and structures	P1: Direct contact
		P2: Vertical migration of contaminants in unsaturated zone
		P3: Horizontal and vertical migration of contaminants within groundwater.
	R1: Construction/Maintenance workers	P1: Direct contact
	R5: Flora and Fauna	P1: Direct contact
	R6: Off-site receptors	P5: Direct contact of soils and groundwater with construction materials.
S3: Potential for asbestos in soil associated with the former historic land uses of the site	R1: Construction/maintenance workers.	P1: Direct contact
S4: Potential for ground gases generated by Made Ground	R1: Construction/Maintenance workers	P4: Vertical and lateral migration of ground gases
	R3: Future site users (via enclosed structures e.g. control kiosk buildings)	
	R6: Off-site receptors	
S5: Potential for off-site sources relating to historic and current land uses	R3: Future site users	P3: Horizontal and vertical migration of contaminants within groundwater.

Potential Source	Potential Receptors	Potential Pathway
S6: Potential for off-site ground gas sources relating to historic and current land uses	R1: Construction/Maintenance workers	P1: Direct contact (inhalation) P4: Vertical and lateral migration of ground gases
	R3: Future site users (via enclosed structures e.g. control kiosk buildings)	P1: Direct contact (inhalation) P4: Vertical and lateral migration of ground gases

4.3.3 Geo-environmental Risk Assessment

At this conceptual stage, geo-environmental risk assessment cannot be progressed quantitatively given the lack of ground investigation data. Nevertheless, clearly historical dredging and landfill sites, areas of raised ground associated with infrastructure and/or flood bunds and areas of historical and current industrial use, present potential contaminant cover areas. Groundwater conditions are likely to be mobile within the River Mersey floodplain areas of Terrain 2 and 3 where superficial deposits are likely to comprise interbedded and potentially channelled groundwater and potentially organic alluvial sequences, hence pathways for contaminate migration will exist.

5 Conclusion

5.1 Engineering considerations and recommended ground investigation objectives

The ground conditions in the study area present a number of geotechnical risks to the scheme proposals. These risks are summarised below in order of severity.

5.1.1 Landfill traverse

Notwithstanding aggressive chemical properties of landfill, landfill is unlikely to constitute suitable subgrade due to high compressibility, low strength and ongoing volume loss due biochemical changes in the landfill mass. Even if the formation level is taken down below the base of the landfill the underlying soils are likely to comprise dredgings or marshland, neither of which is likely to be a suitable subgrade. Ground improvement in the form of cement stabilisation may be required, subject to approval of the regulator. The use of vibrated stone columns may improve the strength of the subgrade, but would not necessarily adequately control the settlement of the pavement foundation.

Use of piled foundations socketed into underlying sandstone to support a highway viaduct would provide bearing resistance and settlement control but would be costly. Piled and other penetrative foundations pose a risk to the existing landfill liner and risk creating pollutant linkages to the underlying Principal Aquifer.

The thickness of landfilled material and nature of underlying soils should be determined by intrusive ground investigation.

All of the above solutions would still require highway to be constructed in cutting in order to achieve acceptable vertical gradients through the landfill. The hazards identified in Section 3.2.2 relating to leachate and subsurface fires will therefore still apply. Although engineering solutions to the problem of weak and compressible subgrades undoubtedly exist, a number of residual risks remain as follows:

- finding sufficient landfill capacity to receive wastes generated by excavation of cuttings, a large proportion of which are likely to be classified as hazardous by the receiving landfill operator;
- risk to the integrity of highway construction posed by aggressive leachates percolating through cut slopes or accumulating in subbase layers; and,
- uncertainty with respect to future off-site disposal costs of solid waste and, potentially, of leachate if leachates entering highway cuttings are collected and tankered off site.

The problems of landfill traverse apply to segments A3, A4, A6 and B6 which comprise the route options identified in Table 5.1.

Table 5.1: Route options that traverse principal landfill sites

Route Option	Arpley Landfill	Gatewarth Farm Landfill
Route 25 D,P(I)	✓	✓
Route 26 D,P(II)	✓	✓
Route 28 D,R(I)		✓
Route 29 D,R(II)	✓	✓
Route 30 D,R(III)		✓
Route 36 E,P(I)	✓	✓
Route 37 E,P(II)	✓	✓
Route 39 E,R(I)	✓	✓
Route 40 E,R(II)		✓
Route 43 F,P(I)	✓	✓
Route 44 F,P(II)	✓	✓
Route 47 F,R(I)	✓	✓
Route 48 F,R(II)		✓
Route 49 F,R(III)	✓	
Route 50 F,S		✓
Route 51G,P(I)	✓	
Route 52 G,P(II)	✓	
Route 55 G,R(II)	✓	
Route 60 H,R(II)	✓	

Source: Route options taken from Western Link Warrington Transport Improvement Schemes, Sift 1 7 April 2017

5.1.2 Tunnelling/deep excavation beneath the Manchester Ship Canal at the Acton Viaduct

It is understood that Phase 1 highway design based on a maximum gradient of 6% requires the road level under the Manchester Ship Canal to –15m AOD (20m bgl). Historical boreholes in the vicinity indicate that rockhead at the tunnel location may be between 10 and 15m bgl (–5 to –10m AOD). Tunnelling works assuming a 5m height to crown are therefore likely to encounter the rockhead boundary; multiple tunnelling machines will dramatically complicate operations. Approach excavations or tunnel shafts will likely encounter superficial deposits.

The depth to the water table is unknown, but it is likely that excavations for approach cuttings to a bored tunnel or a cut and cover tunnel will be undertaken below the watertable. Cut-off walls may be required either side of the canal. Seepage of groundwater through the cut-off wall could result in lowering of the watertable outside the cut-off with possible impacts on the Ship Canal and Acton Grange Viaduct.

Intrusive ground investigation is required to confirm assumptions about the depth to rockhead and provide data on the strength and stiffness of soil and rock deposits.

5.1.3 Compressible ground

Potentially compressible ground in the form of infilled ground, tidal flat deposits and alluvium exits throughout the study area. Localised deposits comprising dredgings and marshland are prevalent adjoining the banks of the Mersey. This ground may be unsuitable for highway foundations and ground improvement may be required in the form of cement stabilisation or geogrids. These deposits unlikely to be suitable founding layer for highway structures, although underlying stiff glacial till may be suitable.

Review of historical maps has found little evidence of historic quarrying or mineral extraction across the study area. Sandpits were identified immediately north of the Manchester Ship Canal at Acton. These are traversed by Segments A3 and A4. There is potential here for greater thickness of compressible ground.

Boreholes are required at intervals along the proposed alignment to determine the subgrade conditions. In addition, boreholes are required at the proposed location bridge abutments/embankment approaches to prove the nature and thickness of soil deposits and the strength and stiffness of underlying rock.

5.1.4 Buried foundations

Route options traversing brownfield sites with a long history of previous industrial development may potentially be affected by buried obstructions such as disused foundations and pipelines. The principal risk is of delay during construction. This risk can be mitigated in part by intrusive ground investigation within the footprint of historical structures and by utilities searches to identify active services near proposed highway pavements and highway structures.

Brownfield sites and areas of historic land use are found to affect Segments A5, A8, B1, B5, B7 and C1 which comprise the route options identified in Table 5.2

Table 5.2: Route segments with high concentrations of previous and current industrial development

Route Option	Area of previous industrial development
Route 29 D,R(II)	Baronet Works along Manchester Ship Canal
Route 36 E,P(I)	Penketh Business Park
Route 37 E,P(II)	Penketh Business Park
Route 39 E,R(I)	Penketh Business Park
Route 40 E,R(II)	Penketh Business Park
Route 41 E,R(III)	Penketh Business Park
Route 43 F,P(I)	Sankey Bridges
Route 44 F,P(II)	Sankey Bridges
Route 47 F,R(I)	Sankey Bridges + Baronet Works
Route 49 F,R(III)	Sankey Bridges
Route 50 F,S(I)	Sankey Bridges
Route 51 G,P(I)	Atherton's Quay
Route 52 G,P(II)	Atherton's Quay
Route 54 G,R(I)	Atherton's Quay + Baronet Works
Route 55 G,R(II)	Atherton's Quay
Route 56 G,S	Atherton's Quay
Route 57 H,P(I)	Bank Quay
Route 58 H,P(II)	Bank Quay
Route 60 H,R(I)	Bank Quay + Baronet Works
Route 61 H,R(II)	Bank Quay
Route 62 H,S	Bank Quay
Route 63 I,P(I)	Bank Quay
Route 64 I,P(II)	Bank Quay
Route 66 I,R(I)	Bank Quay + Baronet Works
Route 67 I,R(II)	Bank Quay
Route 68 I,S	Bank Quay

Route Option	Area of previous industrial development
Route 70 J,R	Bank Quay + Baronet Works
Route 71 J,S	Bank Quay

Source: Route options taken from Western Link Warrington Transport Improvement Schemes, Sift 1 7 April 2017

Appendices

A. Location plan

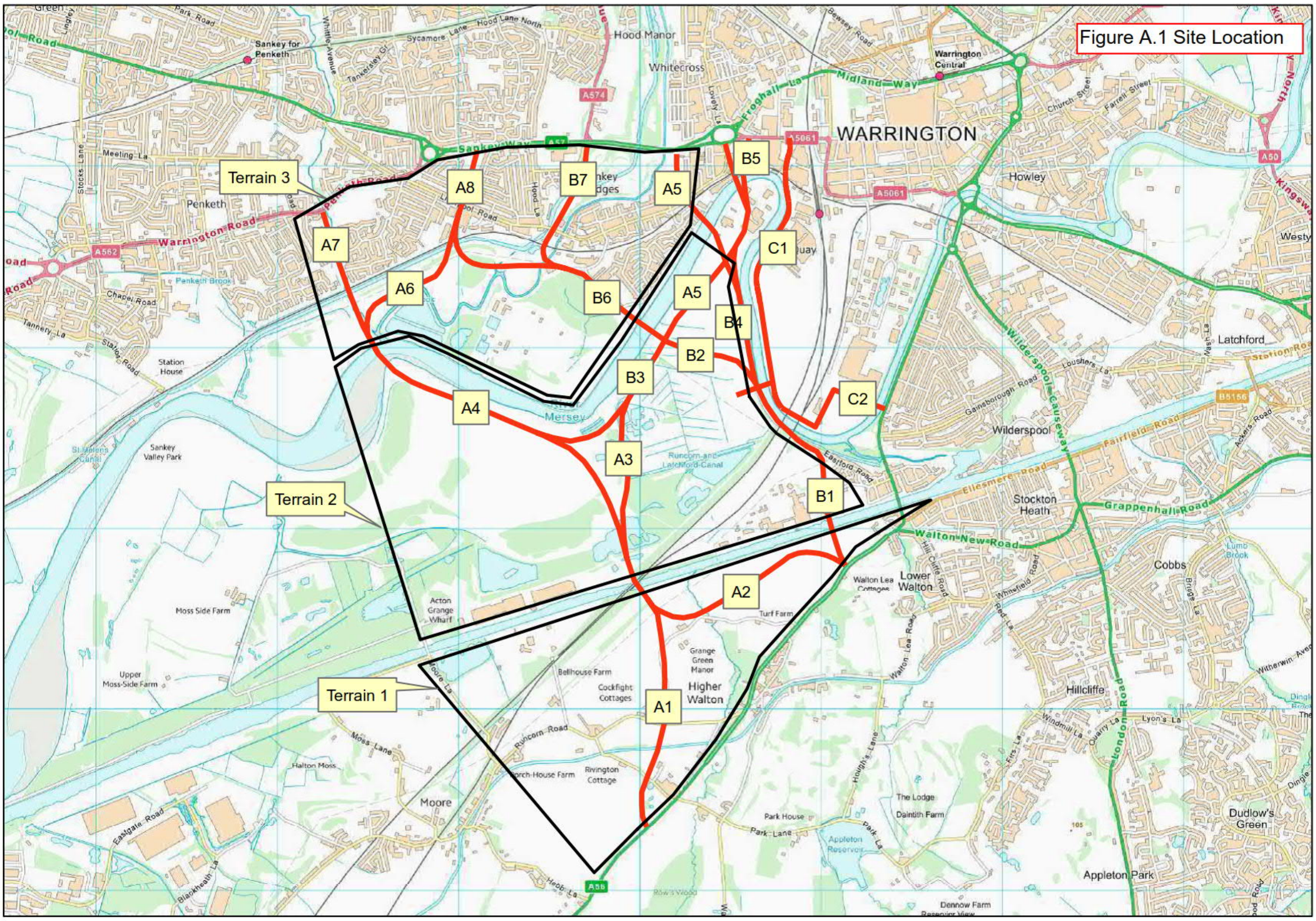


Figure A.1 Site Location
Terrain 1
Terrain 2
Terrain 3
A1
A2
A3
A4
A5
A6
A7
A8
B1
B2
B3
B4
B5
B6
B7
C1
C2
WARRINGTON
Penketh
Hood Manor
Whitecross
Howley
Latchford
Wilderspool
Stockton Heath
Lower Walton
Higher Walton
Hillcliffe
Moore
Cobbs
Appleton Park
Dudlow's Green
Sankey Valley Park
Acton Grange Wharf
Moss Side Farm
Upper Moss-Side Farm
Station House
Sankey for Penketh
Warrington Central
Sankey Way
Warrington Road
Penketh Road
Liverpool Road
Froghall La
Midland Way
Wilderspool Causeway
Walton New Road
Grappenhall Road
Ellesmere Road
Fairfield Road
Runcorn Road
Moss Lane
Moore La
Park Lane
London Road
Runcorn and Latchford Canal
Mersey
Grange Green Manor
Bellhouse Farm
Cockfight Cottages
Turf Farm
Walton Lea Cottages
Park House
The Lodge
Dainith Farm
Halton Moss
Birch-House Farm
Rivington Cottage
Appleton Reservoir
Dennow Farm
A57
A574
A5061
A562
A56
A50
B5156

B. Site photographs

The following are selected photographs from the partial site walkover undertaken on 26 March 2017.

Photo 1: View W with Solvay Interox Ltd chemical works in background

Photo 2: View NW of WCML viaduct across the River Mersey

Photo 3: View NW of zoned residual land on oxbow of River Mersey.

Photo 4: View S of Arpley Landfill site entrance. A portion of the landfill cap is visible on the horizon

Photo 5: View NW of existing Forrest Way Bridge across the River Mersey

Photo 6: View SW from Forrest Way Bridge. Arpley Landfill is visible on the horizon

C. Drawings

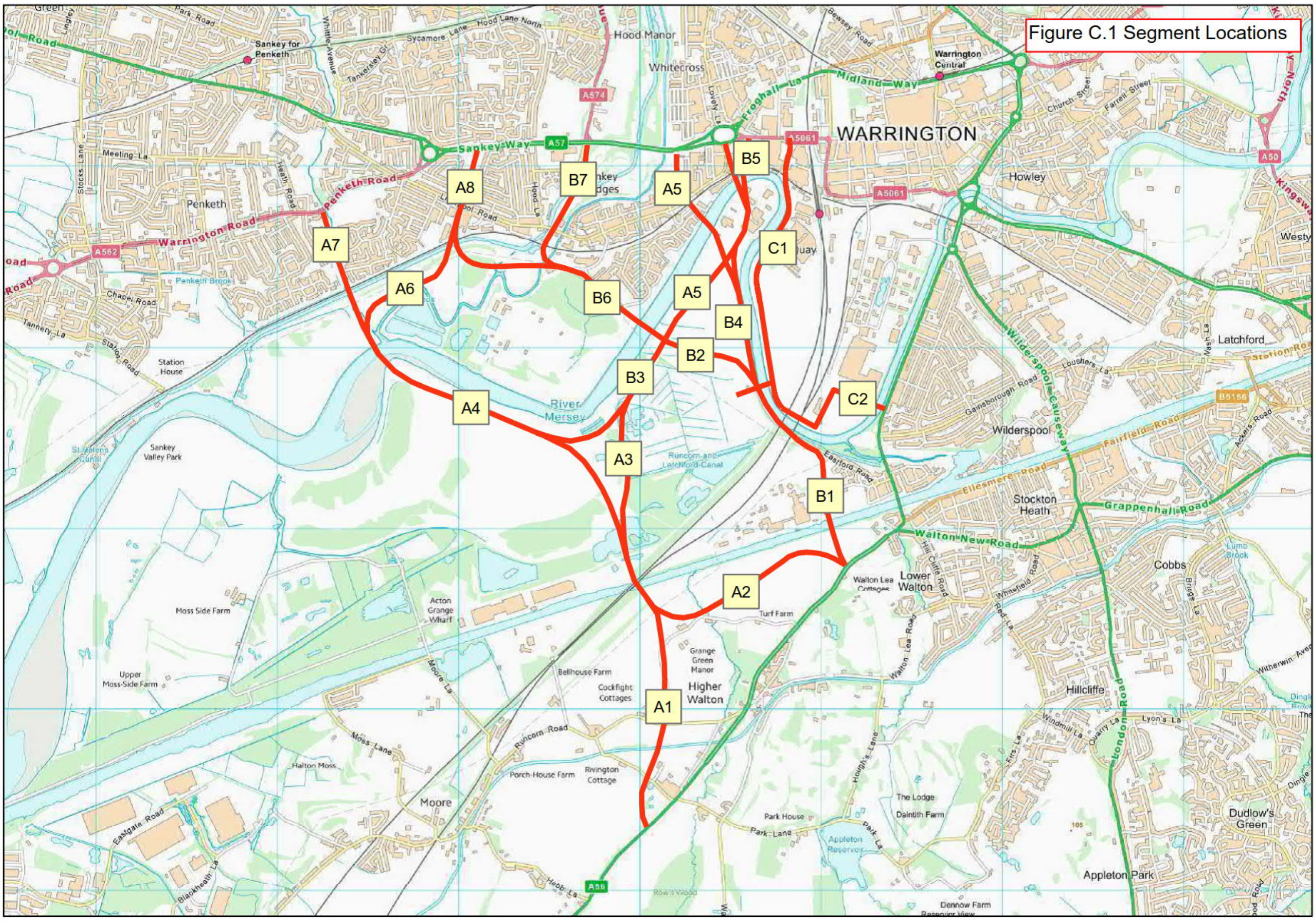
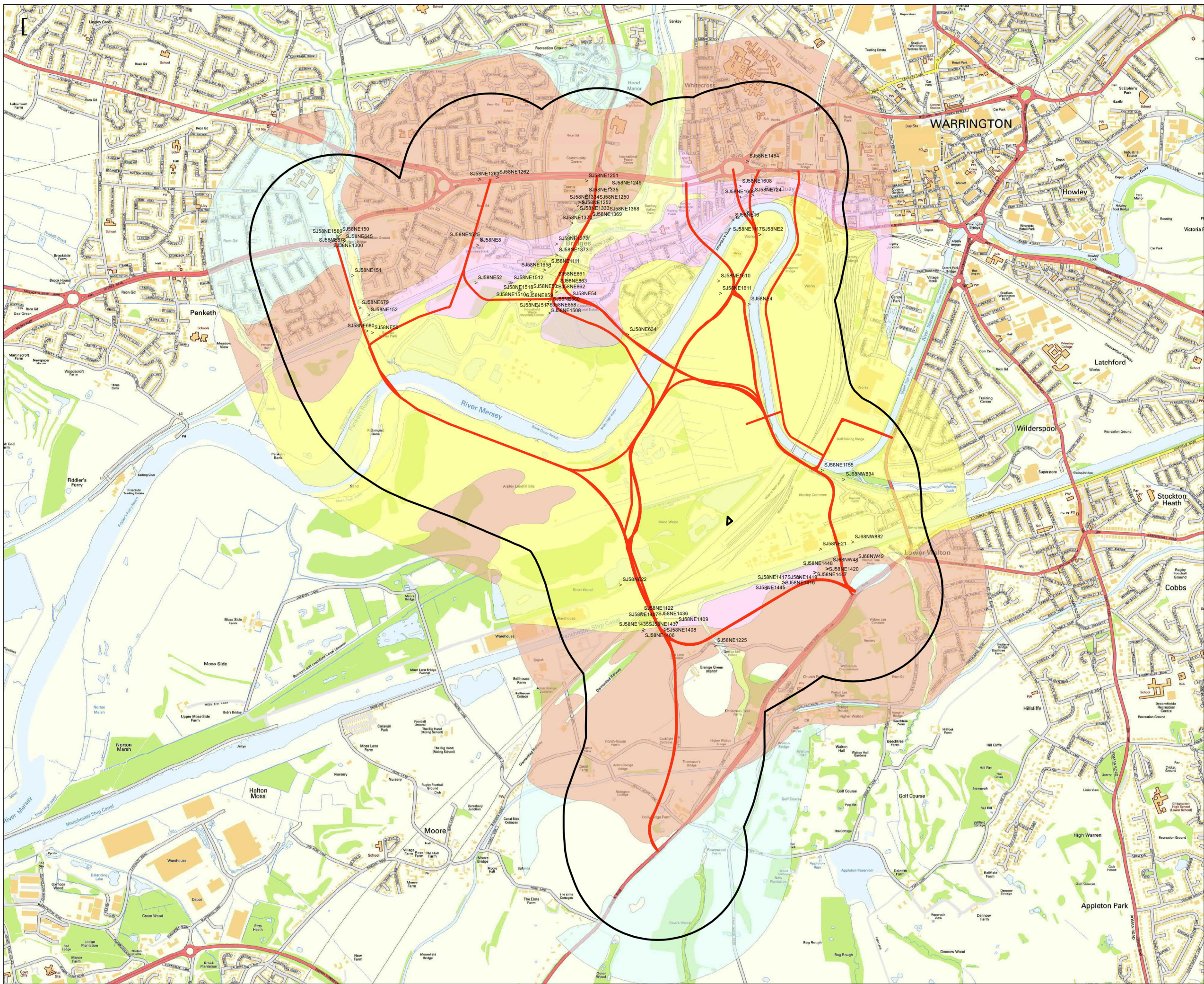


Figure C.1 Segment Locations



Notes

1. This drawing should be read in conjuction with MML Phase 1 Geo-environmental Desk Study Report WL-MMD-07-ZZ-RP-N-0001.
2. Route options are based MML Report Western Link Warrington Transport Improvement Schemes Sift 1 (Ref 382900 02 A 7 April 2017).

Key to Symbols

- Study Area
- Route Options
- > BGS Borehole

LEX_RCS

- ALV-XCZSV
- GFSDD-XSV
- SSA-S
- TFD-XCZS
- TILLD-DMTN

ALV-XCZSV	Alluvium
GFS DD-XSV	Glaciofluvial Sheet Deposits
SSA-S	Shirdley Hill Sand Formation
TFD-X CZS	Tidal Flat Deposits
TILLD-DMTN	Glacial Till

Reference drawings

1. Superficial geology and bedrock geology themes from BGS DigMapGB-10 mapping
2. BGS On-shore Geoindex borehole locations

Rev	Date	Drawn	Description	Ch'k'd	App'd
01	25/04/2017	AC	For Information	NAH	NAH

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Client

Warrington Borough Council

Title

Western Link
Superfical Geology Plan

Designed	AC		Eng Check	NAH	
Drawn	AC		Coordination	AC	
GIS Check			Approved	NAH	

Scale at A1	Status	Rev
1:10,000	INF	P01

Drawing No.
382900-WL-MMD-07-ZZ-GS-N-0001

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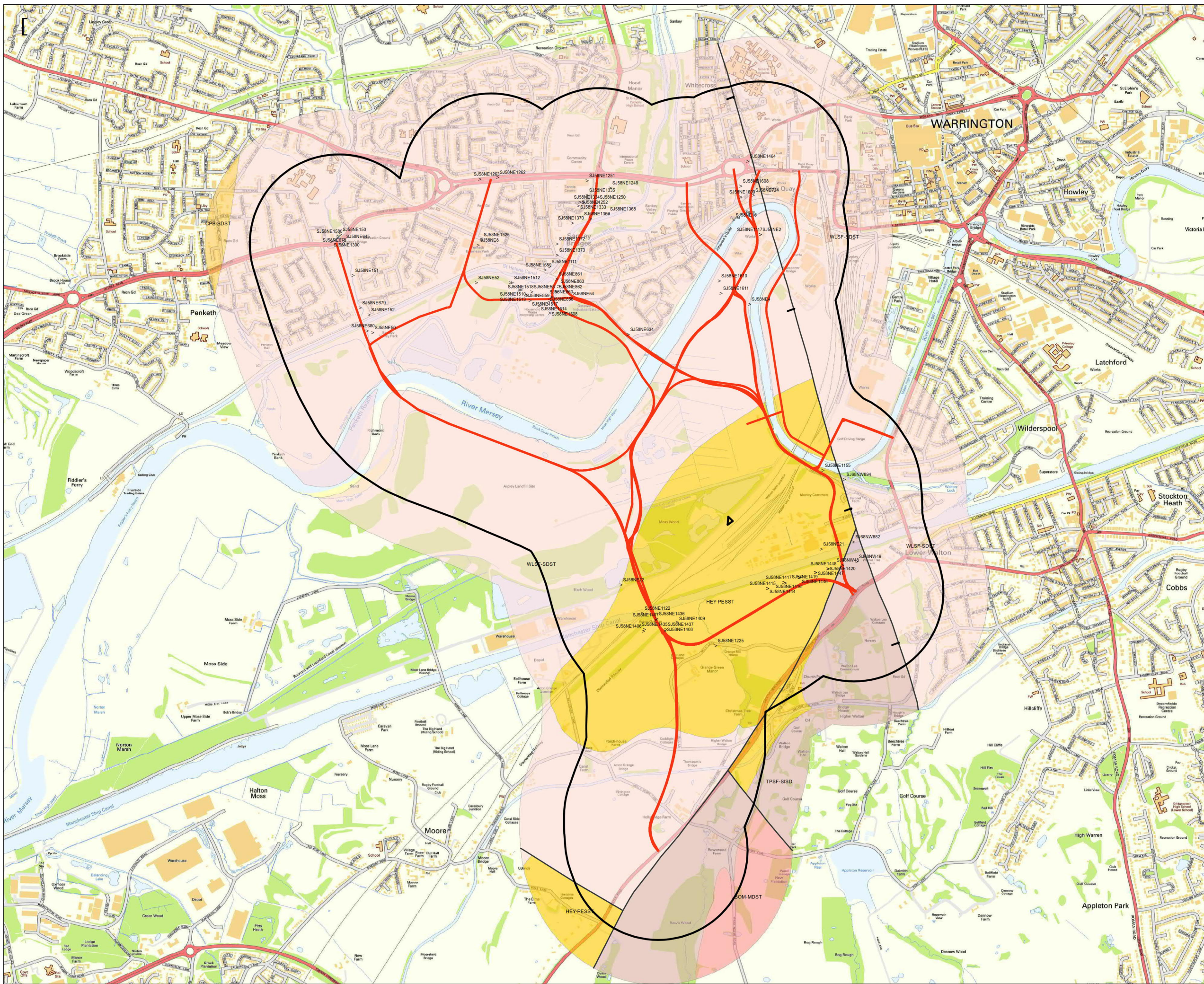

Notes

1. This drawing should be read in conjuction with MML Phase 1 Geo-environmental Desk Study Report WL-MMD-07-ZZ-RP-N-0001.
2. Route options are based on MML Report Western Link Warrington Transport Improvement Schemes Sift 1 (Ref 382900 02 A 7 April 2017).

Key to Symbols

- Study Area
- > BGS Borehole
- Route Options

LEX_RCS

BOM-MDST	*Bollin Mudstone Member (Mercia Mudstone Group)*
TPSF-SISD	*Tarporley Siltstone (Mercia Mudstone Group)*
HEY-PESST	*Helsby Sandstone Formation (Sherwood Sandstone Group)*
WLSF-SDST	*Wilmslow Sandstone Formation (Sherwood Sandstone Group)*
CPB-SDST	*Chester Pebble Beds Formation (Sherwood Sandstone Group)*

- Geological Fault Line (dash indicates downthrow)

Reference drawings

1. Superficial geology and bedrock geology themes from BGS DigMapGB-10 mapping
2. BGS On-shore Geoindex borehole locations

Rev	Date	Drawn	Description	Ch'k'd	App'd
01	25/04/2017	AC	For Information	NAH	NAH

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Western Link
Solid Geology Plan

Designed	AC		Eng Check	NAH	
Drawn	AC		Coordination	AC	
GIS Check			Approved	NAH	

Scale at A1	Status	Rev
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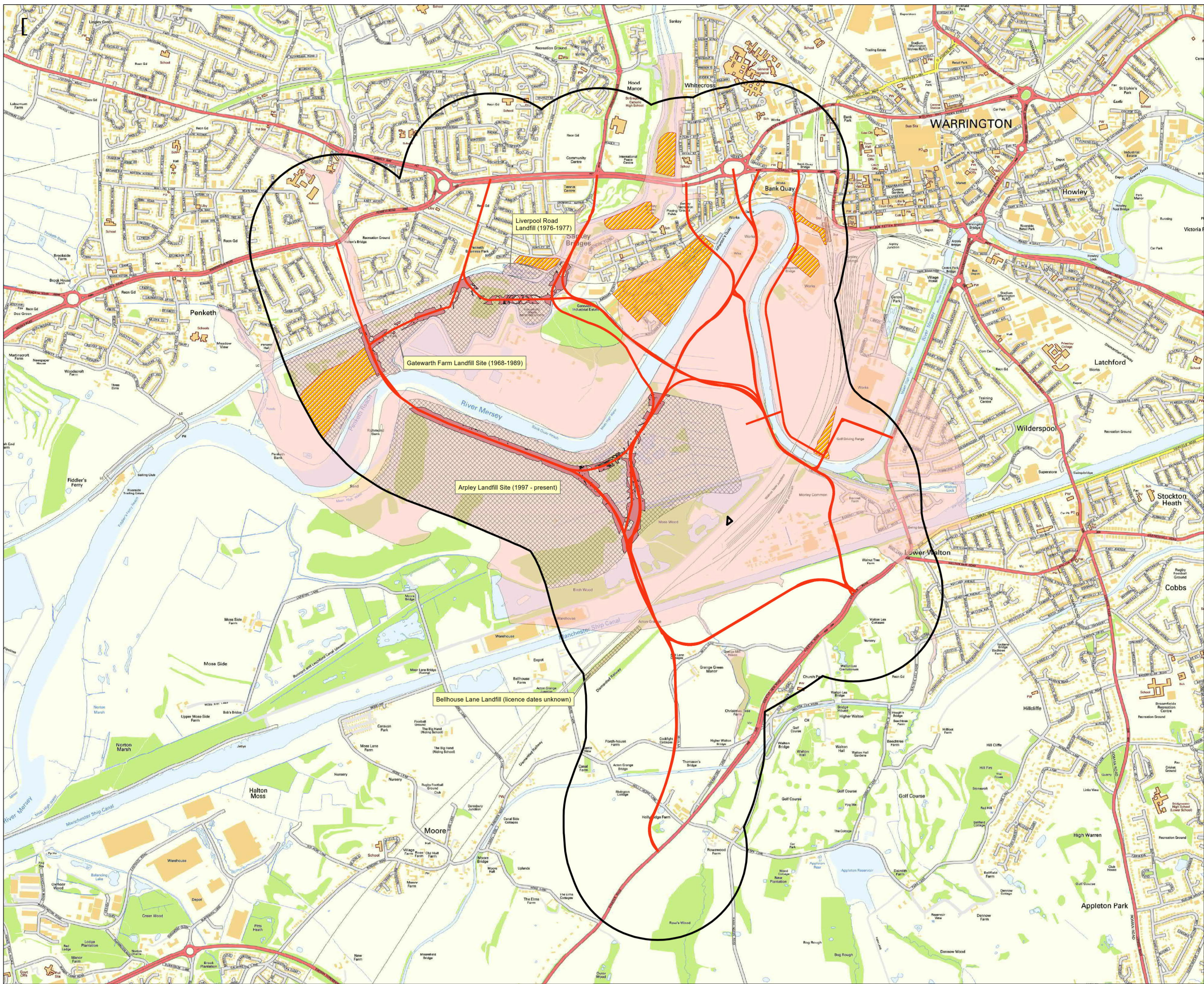

Notes

1. This drawing should be read in conjuction with MML Phase 1 Geo-environmental Desk Study Report WL-MMD-07-RP-ZZ-RP-N-0001.
2. Route options are based MML Report Western Link Warrington Transport Improvement Schemes Sift 1 (Ref 382900 02 A 7 April 2017).
3. The illustrated geotechnical constraints have been derived from the high level datasets described in 'Reference Drawings' below. Further detailed desk study research and instrusive ground investigation will be required to refine the risks in relation to site-specific ground conditions and engineering proposals.

Key to Symbols

- Study Area
- Route Options
- Potential Cut in in Landfill
- Potentially Expansive Ground
- Landfill Site
- Potentially Compressible Ground

Reference drawings

1. Open source LIDAR Composite Digital Terrain Model
2. Landmark 1:10,000 scale Historic Landuse Database (HLUD)
3. Superficial geology and bedrock geology themes from BGS DigMapGB-10 mapping
4. Landmark site-sensitivity data

Rev	Date	Drawn	Description	Ch'k'd	App'd
01	25/04/2017	AC	For Information	NAH	NAH

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Title

Western Link Geotechnical Constraints Plan

Designed	AC		Eng Check	NAH	
Drawn	AC		Coordination	AC	
GIS Check			Approved	NAH	

Scale at A1	Status	Rev
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Drawing No.
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Geotechnical_Constraints(A1 Version) final Apr 25, 2017 - 12:38PM plc54635