Western Link

Ground Investigation Report

20 October 2017

Warrington Borough Council

Mott MacDonald
Spring Bank House
33 Stamford Street
Altrincham WA14 1ES
United Kingdom

T +44 (0)161 926 4000
F +44 (0)161 929 8915
mottmac.com

Warrington Borough Council
Warrington
26-30 Horsemarket Street
WA1 1XL

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Mott MacDonald Limited. Registered in
England and Wales no. 1243967.
Registered office: Mott MacDonald House,
8-10 Sydenham Road, Croydon CR0 2EE,
United Kingdom

Warrington Borough Council

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	20/10/17	A.Carins	N.Haynes	N.Haynes	First issue
		A. Carins	N.Hayns	N.Hayns	

Document reference: 382900-WL-MMD-07-ZZ-RP-N-0002

Information class: Standard

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Contents

Executive summary

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 provide baseline geotechnical and geo-environmental information to inform the Stage 2 Outline Business Case.

A ground investigation was undertaken by Ian Farmer Associates in July 2017 to determine the geotechnical and geo-environmental conditions at locations along the broad land corridors identified at Phase 2A of the proposed Western Link Scheme. The corridors traverse – from south to north – three Terrains:

land between the A56 and the Manchester Ship Canal (Terrain 1);

land between the Manchester Ship Canal and the St Helen's Canal (Terrain 2);

and, land between St Helen's Canal and the A57 (Terrain 3).

The ground investigation encountered significant quantities of manmade deposits in Terrain 2 across which the ground level has been artificially raised above the natural flood plain of the River Mersey. The ground level has been raised by dredge deposits grounds across Arpley Meadows, by landfill deposits at Arpley Landfill and Gatewarth Farm Landfill, and by railway embankments that carry the West Coast Mainline. Localised Made Ground deposits were encountered associated with the Solvay Chemical Plant and with development along the tributaries of the Mersey (Whittle Brook and Sanky Brook).

Manmade deposits are underlain in Terrain 2 predominantly by Tidal Flat Deposits, a soft highly compressible soil that will be an unsuitable bearing stratum for highway earthworks or structures. Embankments above a certain height will require support on piled foundations that penetrate to underlying competent strata. Smaller embankment structures may be founded on Tidal Flat Deposits if such measures as lightweight fill, preloading and geocell reinforcement are adopted. Tidal Flat deposits are largely absent in Terrain 1 and Terrain 3.

In Terrain 2 the Tidal Flat Deposits are underlain by Glacial Till, a silty gravelly clay, in which bands of sand or gravel are interbedded. In the higher-lying Terrain 1 and Terrain 3, the Glacial Till Deposits are encountered nearer the ground surface, often directly beneath Made Ground. Throughout Terrain 1–3 the soil deposits are underlain by sandstone bedrock. Rockhead elevation varies due to the presence of a buried E-W oriented glacial valley across Terrain 2. Both Glacial Till and sandstone bedrock represent competent bearing strata. In Terrain 1 and Terrain 3 bedrock is sufficiently shallow that pile foundations can be designed to resist loads by being socketed into rock. To the north of Terrain 2 where the buried glacial valley is deepest, piles supporting highway embankments and highway structures will likely require to be designed as friction piles within the Glacial Till.

Risks posed by potentially contaminated land outside the landfill areas are considered in this report. It is found that chemical residues from previous land uses pose a low to moderate risk to human health that can mitigated by Personal Protective Equipment and a moderate risk to controlled waters (surface and groundwater). Risk to controlled waters can be mitigated by a piling risk assessment and implementation of construction best practice techniques to prevent the transfer of contaminants to the underlying aquifer.

The Ian Farmer Associates 2017 ground investigation did not include investigation at Arpley Landfill and Gatewarth Farm Landfill, both in Terrain 2. However, Mott MacDonald Limited have undertaken a review of publicly available electronic data files on the two sites held by Warrington Borough Council. Arpley Landfill is licensed to accept the following wastes: Lubricants (oils and greases), antifreeze, Mining/Quarrying wastes, Agricultural wastes, waste from food/wood/leather/oil refining processes, coatings manufacture, thermal processes, construction and demolition waste including asbestos, and asbestos cement. Gatewarth Landfill was used for the disposal of industrial and domestic waste and the site was licensed for the disposal of radioactive material but specific details are not given on this. The Environment Agency has stated that it would object to development of the Yellow Route across Arpley Landfill because of risk to the landfill liner. The Red Route traverses the eastern-most corner of Gatewarth Landfill (an unlined landfill). Although the area of landfill intersected by the route corridor is relatively small, development of the Red Route will require intrusive ground investigation at the landfill to determine material parameters for design purposes and advance waste categorisation of soils for costing and construction stage planning.

1 Introduction

1.1 Scope and Objective of the Report

1.1.1 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 provide baseline geotechnical and geo-environmental information to inform the Stage 2 Outline Business Case.

1.2 Description of Project

1.2.1 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.

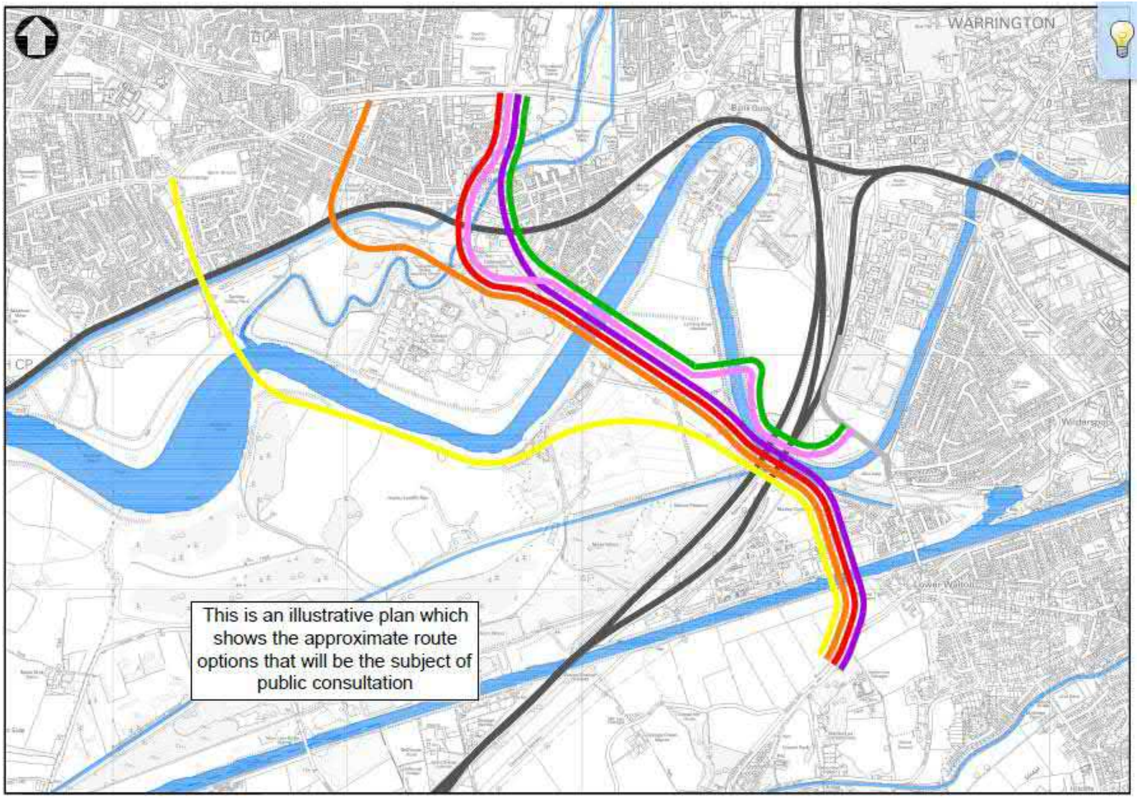
1.2.2 Historically, the River Mersey, Manchester Ship Canal and West Coast Main Line (WCML) railway have acted as barriers that create traffic 'pinch points' on the transfer network. Consequently, traffic between north and south Warrington must go through the town centre, leading to serious congestion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

1.2.3 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 of Warrington town centre.

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

1.2.5 A Stage 1 preliminary sift stage has been undertaken which reduced route options under consideration at Stage 2 sift from 65 to 6. This GIR focuses on the Stage 2 sift options which are detailed in Figure 1 and provided in greater detail in Appendix B. Routes are colour coded for the sift process.

Figure 1: Phase 2A Routes



This is an illustrative plan which shows the approximate route options that will be the subject of public consultation

1.3 Geotechnical Category of Project

1.3.1 At this OBC stage it is anticipated that the proposed Stage 2 alignments will categorise as Geotechnical Category 2 in accordance with Highways England Design Manual for Roads and Bridges (DMRB) Volume 4: Section 1: Part 2 HD22/08 (2008) (Reference1).

2 Existing Information

2.1 Topographic Maps (Old and Recent)

2.1.1 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. Both drawings are included in Appendix B.

2.1.2 From review of LIDAR data, the study area can be divided into three broad terrains (as detailed on WL-MMD-07-ZZ-GS-N-0003):

- Terrain 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 20m AOD at the junction with Chester Road (A56) descending towards the MSC whose banks are at approximately 8m AOD.

- Terrain 2: the area between the MSC and the St. Helens Canal, comprises originally low-lying ground of the River Mersey floodplain. Between the MSC and the River Mersey, 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. North of the Mersey the original floodplain extended to the boundary with the St Helen’s Canal and Sankey Brook, at an elevation of 6mAOD, however between Sankey Brook and the St. Helens Canal, Gatewarth Farm closed landfill has artificially raised ground level to between 8-15m AOD. The original floodplain north of the Mersey now supports a United Utilities Sewage Treatment Works.

- Terrain 3: north of the St. Helens Canal, original ground level rises above the floodplain to elevations of 10-15mAOD. Extensive residential and urban development exists through to the A57.

2.2 Geological Maps and Memoirs

2.2.1 British Geological Survey (BGS) maps indicate that across the lowest-lying areas of the study area (Terrain 2) – 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.

2.2.2 North of the St Helens Canal (Terrain 3) and south of the MSC (Terrain 1) the surface geology is shown as the Shirdley Hill Sand Formation, which comprises a thin layer of blown sand. North of the Mersey local patches of Glaciofluvial Sheet Deposits, consisting of sand and gravel, are shown. The above sequence is likely to be underlain throughout the entire study area by Glacial Till comprising gravelly clay.

2.2.3 South of the Manchester Ship Canal (Terrain 1), moving to higher elevations, the surface geology is shown to consist of Glacial Till, with rockhead anticipated at relatively shallow depth. 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, described as well cemented reddish-brown, locally grey or buff mainly coarse grained, cross-bedded sandstone (BGS Sheet Memoir 109). Across the remainder of the study area the bedrock geology consists of a sequence commencing with strata of the Wilmslow Sandstone Formation, which is described as orange-red to dark brick-red planar cross-stratified non-pebbly, fine-to-medium grained sandstone (BGS Sheet Memoir 123). Coal bearing strata are present but at great depth (>0.75km).

2.2.4 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. The land on which Arpley landfill site was raised originally served as dredging deposits ground, receiving dredgings from the River Mersey and Manchester Ship Canal.

2.2.5 Bedrock contours shown on Sheet Runcorn 97 Drift Edition indicate that south of the River Mersey and along most of the A562/A57 corridor, bedrock elevation varies between 0 and –20m AOD. South of the Manchester Ship Canal bedrock level, where ground level is higher, bedrock elevation is indicated to be between 0 and +20m AOD. Above bedrock, superficial deposits encountered in boreholes comprise sands, slits and clays underlain by glacial till. No publicly available records are available for Arpley Landfill Site.

2.3 Hydrology

2.3.1 Water level at the River Mersey varies from typical low tide of 3.5m AOD to typical high tide of 7m AOD. 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)

2.4 Hydrogeology

2.4.1 The Glaciofluvial sheet deposits that are locally present to the north of the study area are classified as a Secondary A 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.

2.4.2 Secondary A Aquifers are permeable layers capable of supporting water supplies at a local rather than strategic scale. 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.

2.5 Records of Mines and Mineral Deposits

2.5.1 BGS records point to eight sand or gravel pits within the study area. Most of these are pits situated within Terrain 2 in Tidal Flat Deposits. Two are located in the higher lying ground of

Terrain 1 in Triassic bedrock deposits. The locations of the pits are shown on Western Link Geo-environmental Constraints plan WL-MMD-07-ZZ-GS-N-0004.

2.6 Land Use and Soil Survey Information

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

2.6.2 Key developments in industrial land use are the establishment of heavy industry along the northern banks of the River Mersey (in Terrain 2) by the mid to late 19th Century. Industry included iron foundries and metal mills, tool and wire making factories and a soap works, which is today owned and operated by Unilever. Further industrial development ensued following the opening of the Manchester Ship Canal in 1894. The northern bank of the Manchester Ship Canal (Terrain 2) hosted timber processing plants in the first half of the 20th Century, including the Solvay Chemicals plant which is still operational. 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 (both in Terrain 2). Arpley Landfill Site was constructed over former dredging deposits grounds. Arpley Meadows, currently arable land designated for housing development, similarly overlies a historic dredging deposits ground. 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 active. 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.

2.6.3 As part of the Western Link Stage 2A route option assessment, Mott MacDonald have undertaken a review of existing, publicly available electronic data files held by Warrington Borough Council (WBC) for Arpley Landfill Site and Gatewarth Farm Landfill site. A memo reporting the findings of the review is presented in Appendix C. The key findings are detailed in Table 2.1.

Table 2.1: Landfill summary

Landfill	Detail
Arpley Landfill	Arpley Landfill appears in the Warrington Borough Council Database of Potentially Contaminative Land Use from 1993 onwards
	Council records indicate that the landfill is divided into discrete lined cells and that closed cells are covered by an engineered capping layer
	Leachate is collected from each cell and transferred to an on-site treatment plant.
	The environmental permit for the site lists the following permitted wastes: Lubricants (oils and greases), antifreeze, Mining/Quarrying wastes, Agricultural wastes, waste from food/wood/leather/oil refining processes, coatings manufacture, thermal processes, construction and demolition waste including asbestos (ACM), and asbestos cement.
Gatewarth Farm	Gatewarth Farm landfill (130 acres) is a pre-licenced landfill site, subdivided into 3 phases (See Figure 3 Appendix C).
	Planning permission for the tipping of waste at Gatewarth Landfill was granted in 1968, with tipping commencing in 1970.
	Gatewarth Landfill was used for the disposal of industrial and domestic waste and the site was licensed for the disposal of radioactive material but specific details are not given on this.

2.7 Archaeological and Historical Investigations

2.7.1 A statutory heritage constraints map has been prepared which identifies listed buildings in relation to the Phase 2A routes. No archaeological investigation will be undertaken at Phase 2A.

2.8 Existing Ground Investigations

2.8.1 A ground investigation was undertaken on the western edge of Arpley Meadows by Ian Farmer Associates in October 2016 (Reference 2). The purpose of the investigation was to undertake a contamination risk assessment of ground and potential ground gas emissions. The investigation comprised ten window samples boreholes to 5.5m bgl and forty-three trial pits to 4.0m bgl, all set out at 25m grid intervals. The ground investigation encountered layers of very soft to soft clay typically with an organic odour and rare decaying plant remains or fine to medium sand with pockets of clay. Spongy dark grey peat was encountered in three of the trial pits. A thickness of 2.2m was proven; in another trial pit 2.3m thickness was measured but the trial pit was terminated before the base of the peat was reached. Thicknesses of greater than 2.3m may therefore be present.

2.8.2 Drawings WL-MMD-07-ZZ-GS-N-0001 and WL-MMD-07-ZZ-GS-N-0002 (Appendix B) detail publicly available exploratory hole locations.

2.9 Consultation with Statutory Bodies and Agencies

2.9.1 The Environment Agency wrote to Warrington Borough Council 28 July 2017 to state that it would object to any proposals made for the Yellow Route, which crosses Arpley Landfill site, that would damage the structural integrity of the lining system or associated infrastructure on the grounds that this would present a risk to controlled waters.

2.10 Flood Records

2.10.1 A drainage study prepared for the Warrington Centre Park Link by Ramboll entitled *Warrington Centre Park Link Drainage Strategy* (Reference 4) cites a 1 in 100 year fluvial flood event of 6.65m AOD and a 1 in 100 year tidal event of 7.53m AOD.

2.11 Contaminated Land

2.11.1 Historical dredging and landfill sites, areas of raised ground associated with infrastructure and/or flood bunds and areas of historical and current industrial use all present potential contaminant source areas. Groundwater conditions are likely to be mobile within the River Mersey floodplain areas. Soil deposits are likely to contain interbedded and potentially organic alluvial sequences and hence pathways for contaminant migration via groundwater will likely exist; equally significant dispersion of contaminants may be anticipated. A Site Conceptual Model and quantitative risk assessment is presented in Chapter 6.

3 Field and Laboratory Studies

3.1 Walkover Survey

3.1.1 A site walkover was undertaken on 26 March 2017. Photographs from the walkover are included in Appendix B of MM Geo-environmental Phase 1 Desk Study Report WL-MMD-07-ZZ-RP-N-0001.

3.2 Ground Investigation

3.2.1 A site-specific ground investigation was designed by Mott MacDonald Limited to characterise superficial deposits and the depth and quality of underlying bedrock, and to assess identified ground risks.

3.2.2 The ground investigation fieldwork was undertaken by Ian Farmer Associates between 27 June and 27 July 2017.

3.2.3 Three rotary boreholes designated BH07, BH10 and BH12A were excavated to rockhead at depths between 5.2m bgl (at BH12A) and 18m bgl (at BH07) by cable percussion techniques. Thereafter they were advanced by rotary core methods to between 16m bgl (at BH12A) and 30m bgl (at BH07).

3.2.4 Two cable percussion boreholes designated BH03 and BH06A were advanced to rockhead at 16.2m bgl in both cases. Cable percussion boreholes BH04 and BH05 refused in stiff clay at 22.0m and 17.2m bgl, respectively. BH06 was terminated in stiff clay at 12.65m bgl owing to blockage of the bore at that depth by a failed thin wall sampler. Cable percussion boreholes BH04A and BH05A were advanced to 37.8m bgl and 24.48 m bgl without rockhead being encountered.

3.2.5 Six cone penetration test (CPT) soundings CPT01, CPT02, CPT03, CPT04, CPT14 and CPT15 were undertaken using a 20-tonne tracked rig. Except for CPT02, the CPT soundings were paired with an adjacent MOSTAP sample which was continuous throughout the full length of the bore. MOSTAP sample locations are designated CPT01A, CPT03A, CPT04A, CPT14A and CPT15A.

3.2.6 Dissipation tests were undertaken in CPT01, CPT02, CPT14 and CPT15.

3.2.7 BH03, BH04A, BH05A, BH07 and BH10 were fitted with 50mm diameter standpipes. The remaining boreholes were backfilled without installations. 19mm diameter standpipes were installed in CPT14A and CPT15A; these installations were removed after one round of monitoring as permission for post-fieldwork access was not in place.

3.2.8 Groundwater monitoring data is presented in Table A.7

3.2.9 *Geotechnical samples.* Small disturbed samples of cohesive deposits were taken at 0.5m intervals to 10m bgl then at 1m intervals and UT100 samples were taken at 1m intervals to 10m bgl then at 10m intervals. Bulk samples were taken of granular deposits to 10m bgl then at 2m intervals.

3.2.10 *Environmental samples.* Samples were taken in Made Ground at 0.2, 0.5 and 1.0 m bgl. Details of chemical testing undertaken on selected environmental samples are given in Table 2. Groundwater samples were taken on 10 August 2017 from BH03, BH04A, BH05, BH06, BH07 and BH10.

3.3 Other Field Work

3.3.1 Transport Research Laboratory (TRL) probes were undertaken adjacent to inspection pits to a depth of 1.2m bgl. Tests were carried out in accordance with TRL Project Report PR/INT/277/04.

3.3.2 Variable head permeability tests were undertaken in installations within BH03, BH04A, BH05A, BH06A and BH10.

3.4 Laboratory Investigation

3.4.1 Geotechnical laboratory work was undertaken as described in Table 2. All work was undertaken by Ian Farmer Associates in their Newcastle UKAS accredited laboratory (No. 1464).

Table 3.1: Geotechnical and chemical laboratory work (soils and rock)

BS1377 (1990)/ISRM Reference	Number of tests	Test description
Part 2 Section 3.2		Moisture content determination
Part 2 Section 4.3 and 5.3		Liquid and plastic limit determination
Part 2 Section 9.2 and 9.3		Mechanical analysis sieving
Part 3 Section 3.0		Organic matter content
Part 3 Section 4.0		Loss on ignition
Part 7		Single stage quick undrained triaxial
Part 8		Single stage consolidated undrained triaxial
ISRM 2007 (Pages 125–132)		Point load
ISRM Page153 Part 1		UCS

3.4.2 Geo-envionmental laboratory work was undertaken by Concept Life Sciences in Manchester (accredited under the EA’s MCERTS Chemical Testing of Soils analytical performance scheme for selected parameters and also United Kingdom Accreditation Scheme (UKAS) No. 1549). Environmental soil (including soil leachate) and groundwater samples were tested for inorganic and organic contaminants as summarised in Table 3.

Table 2.2: Summary of chemical testing

Location	Depth (m bgl)	Ground unit	Soil Suite	Leachate Suite	WAC
CPT01A	1.2	Made Ground	MM	MM	
CPT03A	1.2	Glacial Till	MM	MM	
CPT14A	1.2	Dredge deposit	MM	MM	
CPT14A	2.4	Dredge deposit	MM		
CPT14A	4.8	Dredge deposit	MM		
CPT15A	1.2	Dredge deposit	MM	MM	
CPT15A	3.6	Dredge deposit	MM		
CPT15A	6.0	Dredge deposit	MM		
BH03	1.0	Glacial Till	MM	MM	
BH04	1.2	Made Ground	MM	MM	YES
BH04	3.0	Made Ground	MM	MM	YES
BH04	4.0	Tidal Flat Deposits	MM	MM	
BH12A	2.0	Made Ground	MM	MM	YES
BH12A	3.0	Made Ground	MM	MM	YES

Location	Depth (m bgl)	Ground unit	Soil Suite	Leachate Suite	WAC
BH12A	4.0	Reworked glaciofluvial deposit	MM	MM	
BH05	1.8	Made Ground	MM	MM	YES
BH05	2.5	Made Ground (possible landfill deposit)	MM	MM	
BH10	0.5	Glacial Till	MM	MM	
BH07	0.5	Tidal Flat Deposits	MM		
BH07	1.0	Tidal Flat Deposits		MM	

4 Ground Summary

4.1 Overview

4.1.1 The following account of ground conditions is based on the 2017 Ian Farmer GI, all publicly available BGS borehole records, data received for Arpley Meadows and data held by WBC on Arpley Meadows and Gatewarth Farm. A geological long-section drawing, WL-MMD-07-ZZ-GS-N-0012, along the central Red Route alignment corridor is provided in Appendix B. Summary tables of ground conditions at Terrain 1, Terrain 2 and Terrain 3 are presented in Table 4.1 – 4.3. BGS mapping records a thin distribution of Shirdley Hill Sands (loose-fine sand) overlying Glacial Till deposits, however the borehole logs suggest interbedded Glacial Deposits.

Table 3.1: Ground conditions summary Terrain 1

Strata	Distribution	Description	Base Elevation (m AOD)	Typical Thickness (m)
Glacial Till (GT) with secondary, interbedded sand deposits (GFD)	Exist across Terrain 1	Firm red/brown sandy clay Grey/brown loose medium grained sand Red/ brown loose fine to medium sand Red dense medium grained sand	17–10	3
Sandstone	Exists across Terrain 1 – rockhead elevation falls towards the Manchester Ship Canal	Hard, red unweathered sandstone Red/brown weathered sandstone	Rockhead is encountered at shallow depth falling towards the north from an elevation of approximately 17m AOD at the tie in to the A56 to approximately 10m AOD at the northern boundary of Terrain 1.	–
Groundwater: Groundwater typically encountered in sand layers overlying bedrock. Groundwater level recorded in BGS borehole SJ58NE1420 at the northern boundary of Terrain 1 at 6m AOD.				

Table 4.2: Ground conditions summary Terrain 2

Strata	Distribution	Description	Base Elevation (m AOD)	Typical Thickness (m)
Arpley Landfill (1997–2017)	Arpley Landfill is situated in the SW of the study area, as indicated on WL-MMD-07-ZZ-GS-N-0004, and is traversed by the Yellow Route. Landfill levels rise to a maximum of 35m AOD	The landfill comprises 5 separate development phases, further subdivided into cells. All cells are lined top, sides and base and side slopes are designed at 1V to 2.5H. Leachate and gas collection systems are active. The Walton, Boundary and Arpley phase areas are traversed by the Yellow Route. Details of backfill are unknown. However permitted wastes include lubricants, anti-freeze, mining/quarrying wastes, agricultural waste, thermal processes, construction and demolition waste, asbestos and asbestos cement.	Approx. 7m AOD	See Note 1
Gatewarth Landfill (1968–1989)	Gatewarth Farm is situated between Sankey Brook and St Helen’s Canal and is traversed by the Yellow Route and the Orange Route. The eastern edge of Gatewarth Farm landfill is clipped by the Red Route.	Unlined. Borehole logs from SKM Enviros 2011 SI indicate landfill waste including rubber, plastic, rags, glass, timber, plastic, metal cans and concrete.	5–6.5m AOD	<=10m
Dredge Deposits (DD) (1927–1993)	3 historic dredging grounds were constructed to accept dredged material to maintain the navigability of the MSC. The location of dredging grounds is detailed on WL-MMD-07-ZZ-GS-N-0004. These areas are typically raised to 11–13m AOD. All routes traverse the former dredge areas.	The deposits were typically pumped during this period into cells retained by perimeter bunds. Primary consolidation of the deposits is anticipated to be complete given the age of the material. The deposits may therefore be considered normally consolidated. CPT14A and CPT15A MOSTAP samples undertaken on the eastern edge of Arpley Meadows recovered loose yellowish brown silty sands. The Ian Farmer Associates 2016 Arpley Meadows GI undertaken on the western edge of Arpley Meadows encountered various interbedded deposits including soft to very soft, black and dark grey silty clay with organic matter, grey silty fine sand and localised lenses of spongy fibrous peat up to 2.5m thick.	6m AOD	5–7m
Made Ground (MG)	Solvay Chemical Works	Very loose, black, very gravelly fine to coarse sand. Gravel is angular, fine and medium including brick and ash.	4.9m AOD	3.6m
Tidal Flat Deposits (TFD)	Exist across the entirety of Terrain 2, derived from the River Mersey floodplain	Soft, greyish brown, sandy silt Yellowish brown, silty fine sand with rare fine gravel and dark grey staining with organic odour	+3 to –1 m AOD	3–7m
Glacial Till (GT)	Underlies the entirety of Terrain 2 save for the Walton Viaduct area where GT is likely to have been eroded away leaving GT directly overlying sandstone	Firm to stiff brown, slightly sandy, slightly gravelly clay. Gravel is subrounded, fine and medium of mixed lithologies	–7m AOD	10m
Sandstone (ST)	Underlies the entirety of Terrain 2	Extremely weak to medium strong reddish brown sandstone. Discontinuities are very closely spaced and subhorizontal, generally 1–4 degrees	See Note 2	–

Groundwater: Groundwater levels on historical borehole logs and recorded in borehole installations from the 2017 Ian Farmer Associates GI range between 4 and 7m AOD, although levels in CPT14A and CPT15A were higher at around 8m AOD. These higher levels are most probably associated with surface water seepage.

Notes

[1] Landfill deposits are expected to be thickest, in the order of 25m, at the peak landfill (35m AOD). The Yellow Route skirts the northern edge of the landfill where the thickness of landfill deposits will be less significant. Proposed ground levels vary between 13m AOD and 8m AOD. It is expected that the route could be underlain by an average of 4.5m of landfill (assuming landfill has been placed from 6m AOD upwards; however, construction may require excavation and remodelling of the landfill envelope.

[2] The ground investigation encountered bedrock in BH10 at Eastford Road and in BH12 at the Solvay chemical works at –6.7m AOD and 3.3m AOD, respectively. BH06A and BH07 near Forrest Way bridge proved bedrock at –10.2m AOD and –16.14m AOD. The fact that no rock was encountered in BH04A and BH05A is evidence for an E-W oriented buried glacial valley to the north of Terrain 2. BH04A was advanced to –29.3m AOD with no rock being encountered, proving that the buried valley is at least 40m thick. BH03 in Sankey Valley Park encountered rock at –6.39m AOD, although as BH03 was a cable percussion and not a rotary cored borehole it is possible that the borehole terminated in a sandstone boulder and that rockhead may be situated at a lower elevation.

Table 4.3: Ground conditions summary Terrain 3

Strata	Distribution	Description	Base Elevation (m AOD)	Typical Thickness (m)
Made Ground (MG)	Thin near surface cover, and localised thickening within Sankey Brook Valley and Whittle Brook	Medium dense, brown, grey and black, slightly clayey, silty angular to subangular/subrounded fine to coarse gravel with occasional cobbles including ash, brick, concrete, plastic and glass	4.5–5.7m AOD	<1m (locally thickening to 5m)
TFD (TFD)	Present in tributaries of the River Mersey (Whittle Brook and Sanky Brook)	Very soft, brown, slightly sand, silty clay with bands of clayey silt	0.0m AOD	5m
Glacial Till (GT) with secondary, interbedded Glaciofluvial Deposits (GFD)	Underlies the entirety of Terrain 3	Stiff becoming very stiff sandy gravelly clay. Gravel is subangular to subrounded, fine to coarse of mixed lithologies Loose slightly gravelly, fine to coarse sand. Gravel is subrounded to rounded, fine and medium including sandstone	Unproven due to presence of buried glacial valley – interbedded GFD encountered to in BH04A from –28.7m to the base of hole at –29.3m AOD	Varies due to glacial valley – 9m thickness encountered in BH06A increasing to at least 26m in BH04A returning to 15m thickness in BH03.
Sandstone (ST)	Underlies the entirety of Terrain 3	Extremely weak to medium strong reddish brown sandstone. Discontinuities are very closely spaced and subhorizontal, generally 1–4 degrees	–	–
Groundwater: BGS historical borehole records refer to water strikes in granular layers within 3m of the ground surface. This is likely to be groundwater perched on underlying, relatively impermeable Glacial Till.				

5 Ground Conditions and Material Properties

5.1 Made Ground

5.1.1 Aside from dredge deposits and landfill areas, Made Ground typically comprised road surface courses and subbase, although thicker Made Ground deposits were encountered locally. These thicker deposits are associated with industrial development immediately north of the Manchester Ship Canal and backfill within the corridor of Whittle Brook and Sankey Valley. Typical descriptions are provided in Tables 4.1 – 4.3. The material is predominantly loose to medium dense and subangular, which, according to BS8004:2015 (Reference 5), would provide strength values in the order of $\varphi'= 30$ degrees.

5.1.2 Landfill deposits and dredge deposits are discussed separately below.

5.2 Landfill

5.2.1 BH05A excavated at the entrance of the Gatewarth Recyling Centre on the closed Gatewarth Landfill Site encountered 1.6m of fine to coarse gravel over 1.1m of gravelly sand containing gravel of ash, brick and glass. These materials are consistent with the mixed Made Ground/landfill refuse recorded in BGS historical borehole records. For details of borehole references see Segment Description L4+L8+L33 in Appendix E of MM Geo-environmental Phase 1 Desk Study Report (Reference 3).

5.2.2 Borehole records from ground investigation at Gatewarth Landfill Site are held by Warrington Borough Council. These records indicate up to 8.8m thickness of landfill waste. From these records, the landfill appears to be unlined; landfill deposits are shown to overlie Tidal Flat Deposits or Glaciofluvial Deposits. Landfill waste is described as including rubber, plastic, rags, glass, timber, plastic, metal cans and concrete.

5.2.3 Arpley Meadows Landfill is privately operated. Records of ground investigation at the site are not in the public domain.

5.2.4 Minimal investigation of landfill areas has been undertaken to date, hence identification of site specific engineering properties cannot be undertaken at this stage.

5.3 Dredge Deposits

5.3.1 CPT14/14A and CPT15/15A on the eastern edge of Arpley Meadows in Terrain 2 encountered very silty fine sand interbedded with sandy silt. Both are interpreted here as dredge deposits to 7.0m bgl based on CPT signature and knowledge of historic topographic levels.

5.3.2 PSD curves prepared from specimens of sand sampled from the dredge deposits describe a silty fine sand or silty fine to medium sand (Figure A.3a). Relative density derived from CPT soundings through this material typically varies between 15 and 25%, representative of loose deposits. The silt horizons encountered in the Dredge Deposits generally classify as intermediate plasticity (MI) (Figure A.2). The internal angle of friction of the sand as derived from CPT soundings (CPT14 and CPT15) varies between 30 and 35 degrees.

5.3.3 SPT N values from the Arpley Meadows investigation vary between 0 and 7. CPT cone resistance varies between 0.5 and 4 MPa. The undrained shear strength of the silt horizons based on *in situ* CPT soundings varies between low and medium (20–75 kPa). Laboratory oedometer testing determined moduli of volume compressibility, m_v, between 0.82 and 1.44 m^2/MN and c_v between 3.2 and 0.3 m^2/year.

5.4 Tidal Flat Deposits

5.4.1 Tidal Flat Deposits, typically comprising soft sandy clay or sandy silt, are present across Terrain 2 and in the low-lying area of Sankey Brook in Terrain 3. PSD curves from samples of this soil unit are presented in Figure A.3b.

5.4.2 The tidal flat deposits generally classify as clay of low plasticity or intermediate plasticity (CL/CI) or a silt of low plasticity (ML) with a consistency index ranging between very soft to soft (Figure A.1). The undrained shear strength of the Tidal Flat Deposits based on undrained triaxial tests and on correlations with SPT N and CPT cone resistance varies between very low to low (10–40 kPa).

5.4.3 Falling head permeability tests undertaken in BH10 and in BH05A (installation response zones both in Tidal Flat Deposits) determined an *in situ* permeability of 1.39 x 10^{-6} m/s and 1.66 x 10^{-5} m/s, respectively. Dissipation tests undertaken at 8.01m and 8.50m bgl during CPT soundings at CPT14 and CPT15 determined coefficients of consolidation, c_{vh}, of 201 and 182 m^2/year, respectively.

5.5 Shirdley Hill Sand

5.5.1 No deposits of this unit were encountered in the 2017 Ian Farmer ground investigation.

5.6 Glacial Till

5.6.1 Glacial Till consisting of firm to stiff and, at depth, very stiff, slightly sandy slightly gravelly clay was encountered across Terrain 2 and Terrain 3. Gravel is subrounded to rounded of mudstone and sandstone and generally grades from fine to medium. At depth the gravel particles grade fine to coarse. Grading curves are provided in Figure A.3c.

5.6.2 Deposits of Glacial Till generally classify as clay of low plasticity (CL) with a consistency index ranging between firm and very stiff (Figure A.1)

5.6.3 The undrained shear strength of Glacial Till based on undrained triaxial tests and on correlations with SPT N varies between medium and extremely high (40–300 kPa). Shear strength data is plotted against reduced level in Figures A.6a–c. The medium strengths cannot be attributed to poor drilling practice as shear strength data derived from CPT soundings shows a similar range of variation. It is notable that the Glacial Till encountered in the north of Terrain 2 and in Terrain 3 attains a shear strength consistently in excess of 100kPa by 3–4m bgl, in contrast to Terrain 1 and the south of Terrain 2, where strengths rarely exceed 100kPa. From CPT soundings the stiffness of high to very high strength Glacial Till (75–300 kPa) varies between 6 and 20 MPa. Medium strength Glacial Till (40–75 kPa) varies between 1 and 6 MPa).

5.6.4 Dissipation tests undertaken in Glacial Till in CPT03 determined a coefficient of consolidation, c_{vh}, of 13 and 27m^2/year. Laboratory oedometer testing determined m_v in the range 0.17–0.07 m2/MN and c_v in the range m^2/year 2.9–0.37.

5.6.5 A falling head permeability test undertaken in BH03 (installation response zone in Glacial Till) determined an *in situ* permeability of 4.09 x 10^{-9} m/s.

5.7 Glacio-Fluvial Deposits

5.7.1 Glacio-Fluvial Deposits comprising loose to medium dense, fine to coarse sand and medium dense, sandy, fine to coarse gravel were recorded in boreholes across Terrain 2 and Terrain 3. Glacio-Fluvial Deposits were typically encountered interbedded within strata of Glacial Till and, less frequently, directly beneath Tidal Flat Deposits. PSD curves are presented in Figure A.3d.

5.7.2 Falling head permeability tests undertaken in BH04A and in BH06A (installation response zones both in Glacial Fluvial Deposits) determined an *in situ* permeability of 3.42 x 10^{-6} m/s and 2.88 x 10^{-5} m/s, respectively.

5.8 Sherwood Sandstone

5.8.1 Rock cores recovered from BH07, BH10 and BH12A are described as extremely weak to medium strong reddish-brown sandstone. Discontinues are very closely spaced and subhorizontal, generally 1–4 degrees.

5.8.2 Core quality data is presented in Figure A.4. With reference to this figure, the rock quality designation (RQD) and solid core recovery (SCR) is consistently low. Total core recovery can be seen to be higher in BH12A than in BH07 and BH10.

5.8.3 Laboratory rock testing included point load, Is_{50}(A) and Is_{50}(D), on intact core sampled between 1.7 and –16.2 m AOD. Only one specimen of rock was suitable for UCS testing and it was therefore not possible to establish a site-specific correlation between measured UCS and Is_{50}(A). A constant of proportionality of 24 was assumed. This yields the UCS values plotted against reduced level in Figure A.5. These values are plotted alongside UCS data derived from SPT N * (linearly extrapolated SPN N counts for test penetrations of less than 300mm) and the single laboratory UCS result determined on a specimen of core from BH10 at –11.2m AOD.

5.8.4 On the basis of 5.8.3 it is suggested that a characteristic rock strength of 1.0MPa is adopted for the purposes of rock socket capacity calculations.

5.9 Groundwater

5.9.1 Groundwater inflows and rising heads of water were encountered in exploratory holes BH03, BH04A, BH05, BH05A, BH10 and BH12A, typically associated with granular horizons in the Tidal Flat Deposits, with Glacio-Fluvial Deposits and with sandstone.

5.9.2 Groundwater monitoring data is presented in Table 5.1 and groundwater levels are plotted by date in Figure A.7. Installations in CPT14A and CPT15A were removed after one round of monitoring due to restrictions on return visits to these locations.

5.9.3 Groundwater monitoring is ongoing, however initial observations suggest that groundwater elevations typically vary between 4 and 7m AOD, consistent with the River Mersey tidal range. Above this range, water head in CPT14A and 15A is minimal (<1m), which would suggest that the Dredge Deposits may be considered dry. The variable readings from BH03 to date may be considered unreliable, possibly a function of surface seepage.

5.10 Ground aggressivity

5.10.1 BRE SD1 testing of 13 soil specimens from all soil units sampled between 1.2 and 26 mbgl from all soil returned concentration of sulphate in 2:1 water/soil extract below 1400 mg/l. The highest concentrations of sulphate were encountered in Made Ground and in Glacial Till at depth. BRE1 SD1 tests on 7 samples of groundwater all returned sulphate concentrations below 400 mg/l. The measured pH of groundwater samples exceeded 5.5 throughout. Given that pile foundations are likely to penetrate Made Ground and Glacial Till it is considered appropriate to adopt a global design sulphate class for spread and pile foundations. On this basis and the assumption of mobile groundwater, the design sulphate class is DS-2 and the ACEC class is AC-2.

5.11 Summary of characteristic geotechnical parameters

5.11.1 Key geotechnical parameters are given for each engineering unit in Table 6. The parameters are intended for preliminary assessment purposes. The geotechnical designer should assess the appropriateness of these characteristic values in relation to specific-structural proposals and the limit state under consideration. In all cases, the appropriate partial factors should be applied to characteristic values in accordance with BS EN1997-1:2004+A1:2013 (Reference 6).

Table 5.1: Summary of groundwater monitoring

			28/07/2017		10/08/2017		24/08/2017		31/08/2017	
Hole ID	GL	Response zone in	SWL		SWL		SWL		SWL	
	(mAOD)		m	mAOD	m	mAOD	m	mAOD	m	mAOD
CPT14A	13.12	DD	5.00	8.12						
CPT15A	13.07	DD	5.43	7.64						
BH05A	8.34	TFD	1.88	6.46	1.88	6.46	1.90	6.44	1.88	6.46
BH10	7.17	TFD	2.00	5.17	1.86	5.31	2.02	5.15	2.30	4.87
BH04A	8.50	GFD			3.12	5.38	3.02	5.48	3.73	4.77
BH06A	6.01	GFD	1.73	4.28	2.17	3.84	2.14	3.87	2.62	3.39
BH03	9.81	GT			2.02	7.79	4.34	5.47	0.44	9.37
BH07	11.58	SST			9.30	2.28	9.46	2.12	9.57	2.01
BH12A	8.49	GFD					3.28	5.21	3.32	5.17

Table 5.2: Summary of characteristic geotechnical parameters

Stratum	Bulk density (kN/m^3)	Φ’	c_u (kPa)	UCS (MPa)	E’ (MPa)	m_V (m^2/MN)	c_V (m^2/yr)	c_{Vh} (m^2/yr)	k (m/s)
Landfill Deposits	10.0[1]	25[1]	–	–	–	–	–	–	–
Dredge Deposits	16.0[2]	30[8]	–	–	3[12]	1.0[14]	1.5[14]	–	–
Granular Made Ground	16.0[2]	30[8]	–	–	3[12]	–	–	–	
Tidal Flat Deposits	20.0[3]	25[8]	20[10]	–	5[12]	0.2[14]		200[15]	9.0 x 10^{-6} [16]
Glacial Till (Terrain 1 only)	17[4]	26[9]	50[10]	–	6[12]	0.14[14]	1.7[14]	20[15]	–
Glacial Till	21.6[3]	28[9]	100[10]	–	25[12]	0.07[14]	2.9[14]	–	4.1 x 10^{-9} [16]
Glaciofluvial Deposits (sand)	18[5]	32[8]	–	–	15[8]	–	–	–	1.6 x 10^{-5} [16]
Glaciofluvial Deposits (gravel)	21[6]	37[8]	–	–	40[8]	–	–	–	
SST	22.1[7]	–	–	1.0[11]	215[13]	–	–	–	

[1] Parameters used by Golder Associates in slope stability analysis of the cell construction at Arpley Landfill site (information viewed by MML at Warrington Borough Council offices 31/05/2017)

[2] Descriptor ‘loose’ and Figure 1 of BS8004:2015

[3] Average of laboratory bulk density tests

[4] Descriptor ‘medium strength’ and Figure 1of BS8004:2015

[5] Descriptor ‘loose’ and Figure 2 of BS8004:2015

[6] Descriptor ‘dense’ and Figure 2 of BS8004:2015

[7] Laboratory bulk density test on rock core

[8] Measured CPT qc and Table D.1 from BS EN 1997:2

[9] Worst credible values based on correlation with plasticity data

[10] cu based on worst credible values from correlation with CPT total cone resistance cu = $(qc - \sigma vo)/Nk$ and Nk=15

[11] Worst credible value from point load and SPT N*. Correlations with SPT N* based on the relationship UCS = 10N MPA after Stroud 1989

[12] E’ based on average of values from correlation with constrained modulus $M = 5\ qc$ after Lunne and Christophersen

[13] Average of all UCS data and the relationship E = 215 X sqrt (UCS) MPa after Rowe and Armitage (1984)

[14] Laboratory oedometer tests

[15] Average of values from dissipation tests

[16] Average of values from falling-head permeability tests

6 Geo-Environmental Review

6.1.1 Soil Analysis Results

The ground conditions are summarised in Section 4 of this report. Contamination testing was conducted on 16 samples during the Ian Farmer Associates site investigation from a range of depths that mainly target the Made Ground. These 16 samples have been analysed for a suite of contaminants including; metals, Polycyclic Aromatic Hydrocarbons (PAHs), Volatile Organic Compounds (VOCs), Total Petroleum Hydrocarbons (TPH), polychlorinated biphenyl (PCBs), pH and asbestos.

The results of the laboratory testing have been compared against current human health generic assessment criteria (GAC). The most appropriate values for the scheme are considered to be LQM/CIEH S4UL's for Human Health Risk Assessment (Reference 7). As the proposed route alignments extend through a range of different land uses, the following S4UL end use assessment criteria have been used;

- Commercial; BH12A
- Residential with produce; BH03, BH04, BH07, CPT 01A, CPT 03A, CPT14A, CPT15A

Specifically, the values have been selected for a soil organic matter (SOM) concentration of 6%. There is currently no S4UL value for Lead, therefore the Defra Category Four Screening Level (C4SL) (CL:AIRE, 2014) (Reference 8) has been used to assess Lead. Selected soil samples were also screened for asbestos.

Several exceedances of the GACs for human health have been identified in the Made Ground. The analyte exceedances are presented in Table 6.1, below and the complete set of soil laboratory test results can be seen in the Ian Farmer Associates factual report (contract number 42103, August 2017).

Table 6.1: Exceedances of the Human Health GACs

	BH ID	**CPT 14A**	**CPT15A**	**CPT15A**	**BH04**
Contaminant	Depth (m bgl)	4.8	1.2	6.0	3.0
	Strata	DD	DD	DD	MG
	S4UL Residential with Produce 6% SOM	**Concentration (mg/kg)**			
Arsenic	37	47	48	69	
Benzo[a]pyrene	3.2				4.3
Benzo[b]fluoranthene	3.9				4.9

The proposed scheme is a highway and a final hardstanding surface will be present on completion of the works. This would therefore break the source-pathway-receptor linkage across the site and it is considered that the risk presented to the end user from site soils will be Low. The depths of contamination are also unlikely to impact upon human health receptors, assuming all excavated material is properly separated and stored.

Selected soil samples were screened for asbestos. No suspected asbestos containing materials were identified in the exploratory hole logs, and laboratory screening confirmed that asbestos was absent in the soil samples tested. However, it should be noted that Arpley Landfill was licensed to accept asbestos waste and the age of Gatewarth Farm landfill (1960s) would suggest that there is potential for asbestos within Gatewarth.

The human health risk assessment and site conceptual model should be reviewed once the final design and location of the preferred route option is determined.

6.1.2 Soil Leachate Results

Soil leachate testing was undertaken on soil samples as part of the Ian Farmer Associates site investigation and the soil leachate results can be seen in the Ian Farmer Associates factual report. This testing is required to assess the suitability of excavated material, with respect to chemical quality and potential risks to controlled waters, for reuse within the scheme, or for disposal off-site.

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) and the Bridgewater Canal.

The Glaciofluvial sheet deposits that are locally present to the north of the study area are classified as a Secondary A 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.

Assessment criteria have been derived from the following sources:

- Drinking Water Standards (DWS), taken from the Water Supply (Water Quality) Regulations 2016 (SI 2016/614); and
- Environmental Quality Standards (EQS) (fresh water).

The results of the soil leachate testing identified the following exceedances (as shown in Table 6.2) of UK DWS and EQS thresholds within the samples tested.

Table 6.2: Soil Leachate exceedances recorded

Location	Depth (m bgl)	Strata	Contaminant	Unit	Result	EQS	DWS
CPT14A	1.2–2.2	DD	Lead as Pb (Dissolved)	µg/l	1.5	1.2	-
CPT15A	1.2–2.2	DD	Lead as Pb (Dissolved)	µg/l	1.3	1.2	-
CPT14A	1.2–2.2	DD	Arsenic as As (Dissolved)	µg/l	14	1	10
CPT15A	1.2–2.2	DD	Arsenic as As (Dissolved)	µg/l	17	1	10
BH04	3.0	MG	Nickel as Ni (Dissolved)	µg/l	5	4	-
BH04	3.0	MG	Ammoniacal Nitrogen as N	mg/l	0.8	-	0.5
BH04	4.0	MG	Ammoniacal Nitrogen as N	mg/l	2.5	1	0.5
BH04	1.0	MG	Ammoniacal Nitrogen as N	mg/l	0.94	-	0.5
BH04	2.0	MG	Arsenic as As (Dissolved)	µg/l	4.5	-	1
BH04	1.0	MG	Arsenic as As (Dissolved)	µg/l	3.6	-	1
BH7	1.0	DD	Nickel as Ni (Dissolved)	µg/l	5	4	

Location	Depth (m bgl)	Strata	Contaminant	Unit	Result	EQS	DWS
BH7	1.0	DD	Arsenic as As (Dissolved)	µg/l	3	1	
BH7	1.0	DD	Cyanide (Total) as CN	µg/l	60	50	

Leachable concentrations of arsenic, lead, nickel, ammoniacal nitrogen, and cyanide were marginally elevated above the DWS / EQS within the soil samples tested via leachate extraction.

It should be noted that leachate extraction is an aggressive form of test and is known to produce considerably higher results than would be expected in the naturally occurring environment.

The risk to controlled waters should be reviewed once the final design and location of the preferred route option is determined.

The Environmental Risk Assessment undertaken by Ian Farmer Associates (Reference 2) also identified elevated concentrations of lead and arsenic. The following remarks are considered pertinent to the present assessment.

Elevated arsenic and lead concentrations are deemed to be widespread across the site. Whilst slight PAH exceedances have been observed, these are not deemed to be sufficiently elevated to represent any significant risk to human health.

The source of the elevated soil concentrations is unclear. The soil chemistry maps indicate that lead concentrations in the vicinity of the site may be raised to the levels observed and there the potential for them to be present at similar levels on site can't be ruled out. However, this would not apply to arsenic.

Another explanation could be for the historical deposition of dredging material from the Mersey on the site. Whilst the engineering logs show no evidence for this, the historical maps indicate the site to be 'mud' and possibly clear of vegetation. It is possible that any material could have been cleared from the area and used within the river embankment, although this is purely speculative. The elevated arsenic and lead may simply be due to the heavy industrial nature of the surrounding area.

Another possibility is the possible historical use of lead arsenate as an insecticide. The field is understood to have been formerly cropped and the use of pesticides and herbicides cannot be ruled out.

6.1.3 Waste Categorisation for Soils

There may be a requirement during construction works to excavate and permanently remove soils from site. The analytical results for the soil samples collected have been assessed using the HazWasteOnlineTM software to provide an indication of the likely waste classification of the soils on site in accordance with guidance given in WM3. It is the responsibility of the waste producer to ensure that all waste created on site undergoes basic characterisation prior to disposal to an appropriate permitted landfill, and an indication of the likely classification is provided here.

It is recommended that the soil laboratory test certificates be discussed with a waste operator, should excavation and off-site disposal of soils be required as part of the development. If the soils cannot be reused onsite either due to their poor engineering properties, and off-site disposal is required, further testing requirements should then be discussed with a waste operator to determine the suitable disposal options.

The initial assessment of the likely classification of excavated soil identified that the following samples were classified as potentially hazardous due to hazardous property HP3(i): Flammable, resulting from concentrations of TPH (C6-C40);

- BH7, BH12A ES4, BH12A ES5, BH12A ES6, BH04 ES6, CPT 01A, CPT 14A, CPT 14A[1], CPT14A[2], CPT15A, CPT15A[1], CPT15A[2].

Environment Agency guidance WM3 [7] states that hazardous property HP3 can be discounted if the waste is solid without a free draining liquid phase. No free phase product or olfactory evidence of hydrocarbon contamination was recorded in the exploratory hole logs.

The sample from the location of BH04 ES5 was classified as hazardous, due to hazardous property HP7: carcinogenic, HP3(i):Flammable, and HP11: Mutagenic, resulting from concentrations of TPH (C6-C40).

The samples from the locations of BH03 ES4, BH04, and CPT 03A were classified as non-hazardous.

Waste Acceptance Criteria

Waste acceptance criteria (WAC) testing has also been conducted on four samples (BH12A ES4, BH12A ES5, BH04 ES5 and BH04). Sample depths and parent strata are given in Table 6.3.

Table 6.3: WAC sample locations and depths

Location	Depth (m bgl)	Unit	WAC status
BH04	1.0	Granular Made Ground	Inert
BH04 ES5	3.0	Granular Made Ground	Non-Hazardous
BH12A ES4	2.0	Granular Made Ground	Hazardous
BH12A ES5	3.0	Granular Made Ground	Hazardous

BH12A ES5 exceeded the inert WAC thresholds for sulphate and total dissolved solids and exceeded the hazardous waste loss on ignition threshold. BH12A ES4 exceeded the hazardous waste loss on ignition threshold. The sample from BH04 ES5 exceeded the inert WAC thresholds for TPH, sulphate and total dissolved solids. The sample from BH04 did not exceed the inert WAC limits.

6.1.4 Ground Gas Assessment

Gas monitoring was undertaken from seven boreholes as part of the Ian Farmer Associates site investigation at the locations of; BH03, BH04A, BH05A, BH06A, BH07, BH10 and BH12A. It should be noted however that four monitoring visits were only undertaken at the locations of BH05A and BH06A, due to the other monitoring wells being either flooded or unable to be located during the monitoring rounds. Results from ground gas monitoring rounds are presented in the Ian Farmer Associates factual report. A summary of the maximum and minimum gas concentrations and flow rates is presented below;

- Flow rates: -1.3 l/hr – 0.3 l/hr.
- Carbon dioxide (CO_2): 0.0%v/v – 15.6%v/v.
- Methane (CH_4): 0.0%v/v – 52.5%v/v
- Hydrogen sulphide (H_2S): 0ppm
- Carbon monoxide (CO): 0ppm – 5ppm.

The highest recorded gas concentrations were of methane, recorded in BH05A (located at the edge of Gatewarth Landfill). This concentration equates to Characteristic Situation 2, low risk, for that location.

It is understood that no sensitive structures, such as those above ground with man entry, are intended to be associated with the proposed Western Link Scheme. Therefore, the gas monitoring summary above is provided for information purposes only and there is no requirement to carry out further investigation of land derived hazardous gases, for the purposes of designing mitigative measures. Should sensitive structures be intended for the scheme at a later date then the ground gas risk will need to be considered further.

The potential risks from ground gases during the construction works are to be dealt with by the Contractor, in accordance with the Confined Space Regulations. Appropriate ground gas monitoring and safety measures should be in place during the works, as the potential presence of ground gases could pose a risk in any confined spaces of deep excavations.

6.1.5 Risk Assessment and CSM

The conceptual site model (CSM) developed in the Mott MacDonald Geo-environmental Phase 1 Desk Study Report (May 2017), has been reviewed to determine whether or not any residual risks remain following the ground investigations. Potential pollutant linkages at the site have been identified in the CSM. An assessment of these risks has been undertaken to identify where unacceptable risks may be present and if further assessment or remedial actions are required to mitigate risks during and following construction. It should be noted that several locations of the proposed route alignments, notably Arpley Landfill and Gatewarth Landfill sites, could not be accessed during the Ian Farmer Associates ground investigation and the potential risks from these locations have therefore not been assessed.

The Environment Agency wrote to Warrington Borough Council 28 July 2017 to state that it would object to any proposals made for the Yellow Route, which crosses Arpley Landfill site, that would damage the structural integrity of the lining system or associated infrastructure on the grounds that this would present a risk to controlled waters.

The risk assessment has been produced making the following assumptions:

- That construction best practice techniques will be implemented, and thus risks from spills and leaks during construction have not be included in the assessment; and
- As there is no change in land-use, and under the assumption that any excavated material will be appropriately removed from site, there is no pathway to site end users and thus they have not been included in the model.

Table 6.4: Site Conceptual Model

Potential Source	Potential Receptors	Potential Pathway	Consequence	Probability	Risk	Mitigation measure
S1: Potentially contaminated Made Ground relating to current and historic land uses	R1: Construction /Maintenance workers	P1: Direct contact	Medium	Low Likelihood	Moderate/ Low	1
	R3: Future site users R5: Flora & Fauna R6: Off-site receptors	P1: Direct contact	Medium	Low Likelihood	Moderate/ Low	Contaminant linkage is broken, as no pathway will exist
	R2: Controlled Waters (groundwater)	P2: Vertical migration of contaminants in unsaturated zone	Medium	Low Likelihood	Moderate	2
		P3: Horizontal and vertical migration of contaminants within groundwater.	Medium	Low Likelihood	Moderate	2
		P6: Man-made contaminant transport pathways (services, piled foundations)	Medium	Low Likelihood	Moderate	2
S2: Potentially contaminated Groundwater relating to current and historic land uses	R4: Buried services and structures	P1: Direct contact	Medium	Likely	Moderate	3
	R1: Construction workers	P1: Direct contact	Medium	Low Likelihood	Moderate/ Low	1
S4: Potential for on and off-site ground gas sources relating to historic and current land uses	R1: Construction workers	P1: Direct contact (inhalation) P4: Vertical and lateral migration of ground gases	Severe	Low Likelihood	Low	1

The following mitigations should be implemented throughout construction to enable the risks to remain low to very low:

Mitigation measure 1 – Appropriate personal protective equipment (PPE), including monitoring in excavations and respiratory protective equipment (RPE) as appropriate, should be worn by all construction workers to minimise exposure to any contaminated materials/leachate/ perched water/ ground gas in the Made Ground.

Mitigation measure 2 – Principal Aquifers underlying the site including Glaciofluvial sheet deposits and the Wilmslow Sandstone Formation. Secondary B Aquifer of The Helsby

Sandstone Formation. The presence of a clay layer beneath the Made Ground, although not consistently across the site, is likely to act as an aquitard, preventing infiltration and thus removing this pathway, from the strata above into the underlying aquifers. A piling risk assessment should be undertaken once the preferred route has been determined and Construction best practice techniques should be implemented to ensure the transfer of contaminants to the underlying aquifer does not occur.

Any changes in drainage as a result of the proposed scheme should ensure no transfer of contaminants from the site to nearby surface water features.

Should dewatering be required, testing of the groundwater at the de-watering locations should be carried out to assess appropriate treatment or disposal options. Where dewatering is required, an environmental permit may be required where it is proposed to discharge dewatering effluent into surface waters or onto the ground. Should contamination be present, a permit will be required to determine an appropriate disposal location.

Mitigation measure 3 - Materials used in the construction should be designed with the ground conditions in mind. Details of aggressive ground conditions are included in Section 5.

Recommendations

In addition to the mitigation measures outlined above it is recommended that:

i. A construction environmental management plan is produced and implemented to ensure appropriate storage and disposal of excavated materials, in addition to employing construction best practice throughout the project.
ii. The presence of hazardous materials within the made ground means any excavated material may not be suitable for re-use in its current state, and this will require treatment or appropriate disposal. Any waste removed from site will need to be tested and treated or disposed of at an appropriately licenced landfill.
iii. Further ground investigation and assessment will be required once the proposed route alignment and design has been confirmed.

7 Geotechnical Design Considerations

7.1 Geotechnical design considerations

7.1.1 Cut slopes are proposed at Chainage 1150–1300 on the eastern edge of Arpley Meadows. This area is part of a former dredging deposits ground. For costing purposes a slope angle of 1 (V) in 2.5 (H) is recommended for cut slopes in Dredge Deposits. Slope angles and slope drainage measures such as counterfort drains will need to be confirmed at detailed design stages, subject to investigation of ground and groundwater conditions at the cut face. Investigation to date, however, does suggest that the Dredge Deposits are dry.

7.1.2 For regrading of landfill deposits across Arpley Landfill, slope angles of 1 (V) in 3.0 (H) are recommended. Slope angles are subject to confirmation a detail design stage.

7.2 Material reuse

7.2.1 The principal deposits into which highway cuttings will be formed, from which material could potentially be won for engineering use, are the Tidal Flat Deposits and Dredge Deposits on the eastern edge of Arpley Meadows. Neither unit is likely to classify as suitable as engineering material on account of high organic content.

7.2.2 Cut into landfill deposits over Arpley Landfill will most likely yield material that will be classified as hazardous.

7.2.3 The relatively shallow depth to rockhead over Terrain 1, means the area is a potential source of sandstone which could be crushed on-site to sand or gravel.

7.3 Proposed highway structures

7.3.1 Preliminary design considerations for each proposed road bridge structure are discussed in Mott MacDonald Phase 2A bridge summary sheets WL-MMD-07-ZZ-RP-S-0100 to WL-MMD-07-ZZ-RP-S-1100. It is expected that abutment and pier foundations will be supported on piled foundations and the piles will be socketed into sandstone bedrock where rockhead is shallow (less than 20m bgl). Where rockhead is not shallow, piles are expected to be designed as friction piles embedded in stiff Glacial Till.

7.3.2 Approximate rockhead elevations at each proposed structure are given in Table 7.1. Piles that are socketed into sandstone are estimated to develop an ultimate unit shaft friction of 250 kPa. For a 0.9m diameter pile, this equates to an ultimate resistance of 700kN per metre. Piles embedded in stiff Glacial Till are estimated to develop an ultimate shaft friction of 70 kPa, translating into an ultimate resistance of 200 kN per metre for a 0.9m diameter pile.

Table 7.1: Ground model and average rockhead depth by bridge structure

Highway Bridge Structure	Routes	Ground Model	Approximate depth of rockhead
Manchester Ship Canal	Yellow, Orange, Red, Purple	GT over SS (south of SC), MG/TFD over SS (north of SC)	3m south of SC, 5m north
Walton Viaduct	Yellow, Orange, Red, Purple	TFD over SS	6m
Forrest Way	Yellow, Orange, Red,	TFD over GT over SS	15m

Highway Bridge Structure	Routes	Ground Model	Approximate depth of rockhead
	Purple, Green, Pink		
East Ditton Goods Rail Viaduct	Purple, Green	TFD over GT over SS	>40m
West Ditton Goods Rail Viaduct	Red, Pink	TFD over GT over SS	>40m
St Helen’s Canal	Red, Pink, Purple, Green	TFD over GT over SS	>40m
Sankey Brook Bridge	Orange	TFD over GT over SS	>40m
Ditton Rail and St Helens Canal Bridge	Orange	GT over SS	35m
Eastford Road Mersey Crossing	Pink and Green	TFD over SS	6m

Key
TFD – Tidal Flat Deposits
GT– Glacial Till
SS – Sandstone

8 Geotechnical & Geo-Environmental Risk Register

RISK REGISTER

Date:27/09/2017 **Project Phase: Phase 2A** **Project:** **Western Link**

NOTE: RISK TYPES; HS = Health & Safety, T = Time, C = Cost, R = Reputation, E = Environment
Risk: I = Intolerable, S = Significant, T = Tolerable, N = Negligible
Likelihood: VL = Very Low, L = Low, M = Medium, H = High, VH = Very High
Impact: VL = Very Low, L = Low, M = Medium, H = High, VH = Very High

Details of Impact, Likelihood and Risk Classifications are provided in Appendix G

Hazard	Consequences	IMPACT	LIKELIHOOD	RISK	RISK TYPE	Potential Risk Control Measures / Actions	IMPACT	LIKELIHOOD	RESIDUAL RISK
Compressible Ground	Settlement of highways structures and/or pavements. Where highways structures/and or pavements pass over the edge of backfilled areas or pass across a transition from Tidal Flat Deposits to denser natural deposits, marked differential movement could occur with possible impacts on the gradient of highways drainage and ride quality. Potential for foundation failure.	M	H	S	C	Intrusive ground investigation to determine thickness of Tidal Flat Deposits and Made Ground in relation to route options. Use of ground improvement and or piled foundations to limit settlement of highway structures over fill or compressible ground of significant thickness. Potential significant impact on construction cost and programme. Liaise with ECI contractor to evaluate risk. GI undertaken to date indicates the Dredge Deposits and Tidal Flat Deposits are granular dominant, hence settlement s may be anticipated to occur relatively rapidly. Further, route-specific GI should be undertaken at future design stages.	M	M	T
Landfill traverse	Failure of foundations bearing on weak landfilled material. Very large amounts of settlement can be anticipated on the biodegradable materials known to have been deposited at Gatewarth Farm Landfill and Arpley Landfill. Risk to landfill liner by the use of penetrative foundation solutions.	H	VH	I	C	Consultation with EA to determine feasibility of obtaining regulatory approval to construct on former landfill sites and to obtain permits to undertake intrusive ground investigation to determine the thickness and nature of deposits. Undertake foundation strategy assessment to explore engineering solutions. EA correspondence states that they will oppose any routes which impact Arpley Landfill.	H	H	S
Buried foundations and infrastructure	Delays caused by grubbing out of obstructions. Potential for hard spots and differential settlement of highway structures and/or pavements. Potentially high within former developed areas around St Helen's Canal and within landfill crossings; elsewhere low risk.	M	M	T	T	Intrusive ground investigation at brownfield sites intersected by route options in order to determine the thickness and nature of Made Ground and identify the presence of buried obstructions. GI undertaken to date did not encounter obstructions.	M	L	T
Mass haul balance	Road construction dependent upon route option will require the crossing of up to six water bodies and railways and hence there will be a requirement for agreed embankment structures. Moreover, excavated landfill material and alluvial floodplain material is likely to be of low potential for material re-use and hence there is potential for a significant amount of required material input.	H	H	S	C	GI to understand the extent of compressible ground combined with further route vertical alignment development to allow assessment of mass haul. GI suggests that there may be potential for reuse of Glacial Till and Dredge Deposits. However, Tidal Flat Deposits are likely to be too organic for engineering reuse. Locally, Dredge Deposits may also prove too organic for reuse.	H	M	S
Hydrostatic uplift beneath highway cut at Eastford Road	The road level at Eastford Road alongside the Rivier Mersey must be lowered between Chainage 880 and 1080m. The lowest formation level will be approximately 5.3 mAOD, which is below typical high tide level of 7m AOD. On removal of the existing overburden there is a risk that porewater pressures will cause the base of the cutting to fail.	H	H	S	C	Sheet pile cutoff to facilitate construction of the cutting 'in the dry' Basal highway slab anchored by tension piles to resist uplift forces. Impact on adjoining Network Rail structures would require assessment.	H	VL	N

9 Conclusion

9.1.1 A ground investigation was undertaken by Ian Farmer Associates in July 2017 to determine the geotechnical and geo-environmental conditions at locations along the broad land corridors identified at Phase 2A of the proposed Western Link Scheme. The corridors traverse—from south to north—three Terrains:

- land between the A56 and the Manchester Ship Canal (Terrain 1);
- land between the Manchester Ship Canal and the St Helen’s Canal (Terrain 2);
- and, land between St Helen’s Canal and the A57 (Terrain 3).

9.1.2 The ground investigation encountered significant quantities of manmade deposits in Terrain 2 across which the ground level has been artificially raised above the natural flood plain of the River Mersey. The ground level has been raised by the dredge deposits grounds across Arpley Meadows, landfill deposits at Arpley Landfill and Gatewarth Farm Landfill, and railway embankments that carry the West Coast Mainline. Localised Made Ground deposits were encountered associated with the Solvay Chemical Plant and with development along the tributaries of the Mersey (Whittle Brook and Sanky Brook).

9.1.3 Risks associated with dredge deposits are settlement of highways structure and/or pavements. Ground risks associated with construction on landfill are very large amounts of settlement, especially over Arpley Landfill. Design solutions developed for Phase 2 costing purposes seek to minimise settlement by either removing landfill deposits from beneath the highway corridor across Arpley or, across Gatewarth Farm landfill, opting for piled foundations which transfer the loads of highway embankments and structures to underlying competent natural strata. Across Dredge Deposits it is recommended that the highway corridor is preloaded and constructed on geo-cell reinforcement.

9.1.4 Risks posed by potentially contaminated land outside the landfill areas have been considered in this report and it can be concluded that chemical residues from previous land uses pose a low to moderate risk to human health that can mitigated by Personal Protective Equipment and a moderate risk to controlled waters (surface and groundwater). Risk to controlled waters can be mitigated by piling a risk assessment and implementation of construction best practice techniques to prevent the transfer of contaminants to the underlying aquifer. HazwasteOnline assessments classify the Dredge Deposits and TFD as hazardous waste due to high organic content.

9.1.5 Manmade deposits are underlain in Terrain 2 predominantly by Tidal Flat Deposits, a soft highly compressible soil that will be an unsuitable bearing stratum for highway earthworks or structures. Embankments above a certain height will require support on piled foundations that penetrate down to underlying competent strata. Smaller embankment structures may be founded on Tidal Flat Deposits if such measures as lightweight fill or surcharging, or both, are adopted. Tidal Flat deposits are largely absent in Terrain 1 and Terrain 3.

9.1.6 In Terrain 2 the Tidal Flat Deposits are underlain by Glacial Till, a silty gravelly clay, in which bands of sand or gravel are interbedded. In the higher-lying Terrain 1 and Terrain 3, the Glacial Till Deposits are encountered nearer the ground surface, often directly beneath Made Ground. Throughout Terrain 1–3 the soil deposits are underlain by sandstone bedrock. Rockhead elevation varies due to the presence of a buried E-W oriented glacial valley across Terrain 2. Both Glacial Till and sandstone bedrock represent competent bearing strata. In Terrain 1 and Terrain 3 bedrock is sufficiently shallow that pile foundations can be designed to resist loads by being socketed into rock. To the north of Terrain 2 where the buried glacial valley is deepest, piles supporting highway embankments and highway structures will likely require to be designed as friction piles within the Glacial Till.

10 References

1. Highways England Design Manual for Roads and Bridges (DMRB) Volume4: Section 1: Part 2 HD22/08 (2008) *Managing Geotechnical Risk*
2. Ian Farmer Associates *Report on Ground Investigation carried out at Arpley Meadows, Warrington,* Contract No:41932 December 2016
3. Mott MacDonald Limited *Western Link Geo-environmental Phase 1 Desk Study Report* 382900-WL-MMD-07-ZZ-RP-N-0001 25 April 2017
4. Ramboll *Warrington Centre Park Link Drainage Strategy* Ref CPL-RAM-05-ZZ-RP-J-0002
5. British Standards Institution *Code of practice for foundations* BS 8004:2015
6. British Standards Institution *Eurocode 7 Geotechnical Design Part 1:General rules* BS EN 1997-1:2004 Incorporating corrigendum February 2009
7. Nathanail, C.P.; McCaffrey,C.; Gillett, A.G.; Ogden, R.C. & Nathanail, J.F. *The LQM/CIEH S4ULs for Human Health Risk Assessment,* Land Quality Press, Nottingham 2015
8. Contaminated Land: Applications in Real Environments (CL:AIRE) Appendix H Provision C4SLS for Lead to *SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination Final Project Report,* September 2014

Appendices

A. Figures

Figure A.1: SPT N/N* against reduced level

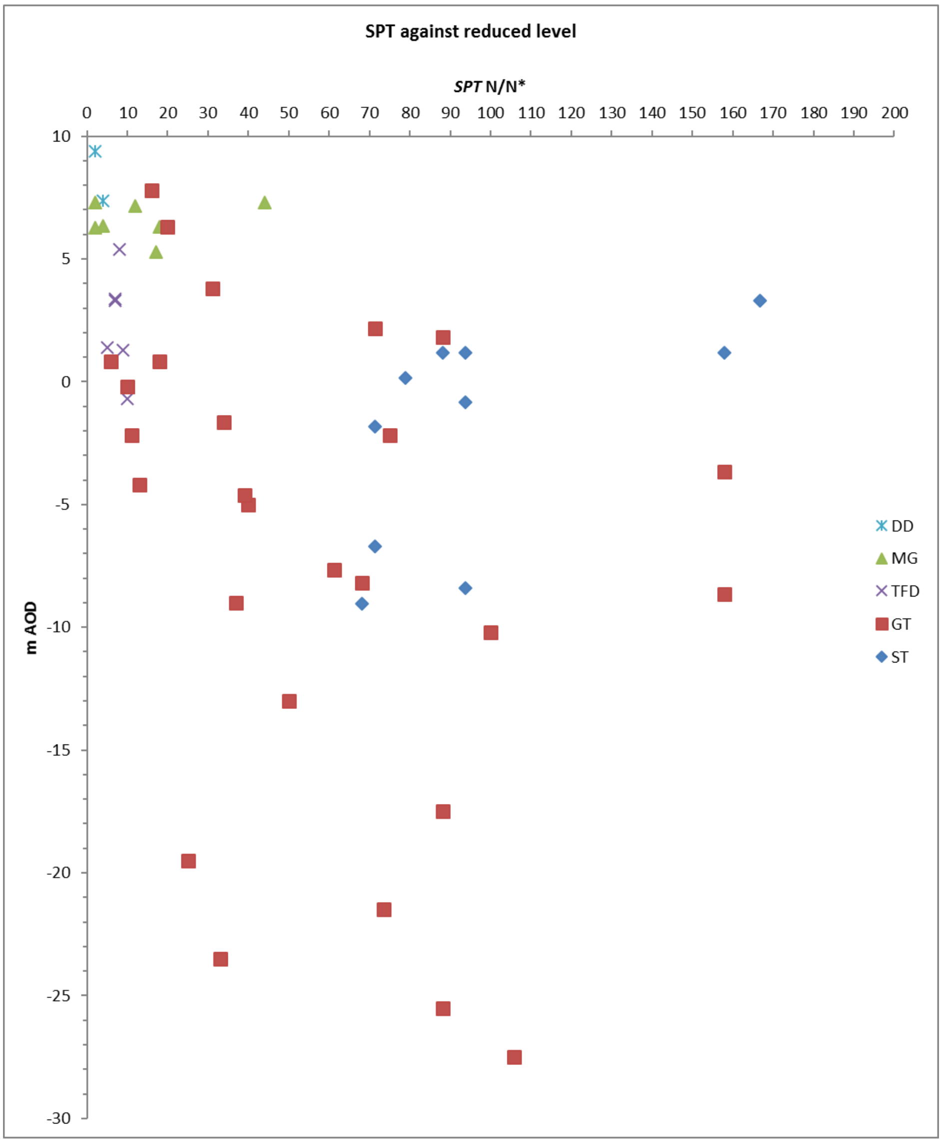


Figure A.2: Plastic limit, moisture content and liquid limit against level

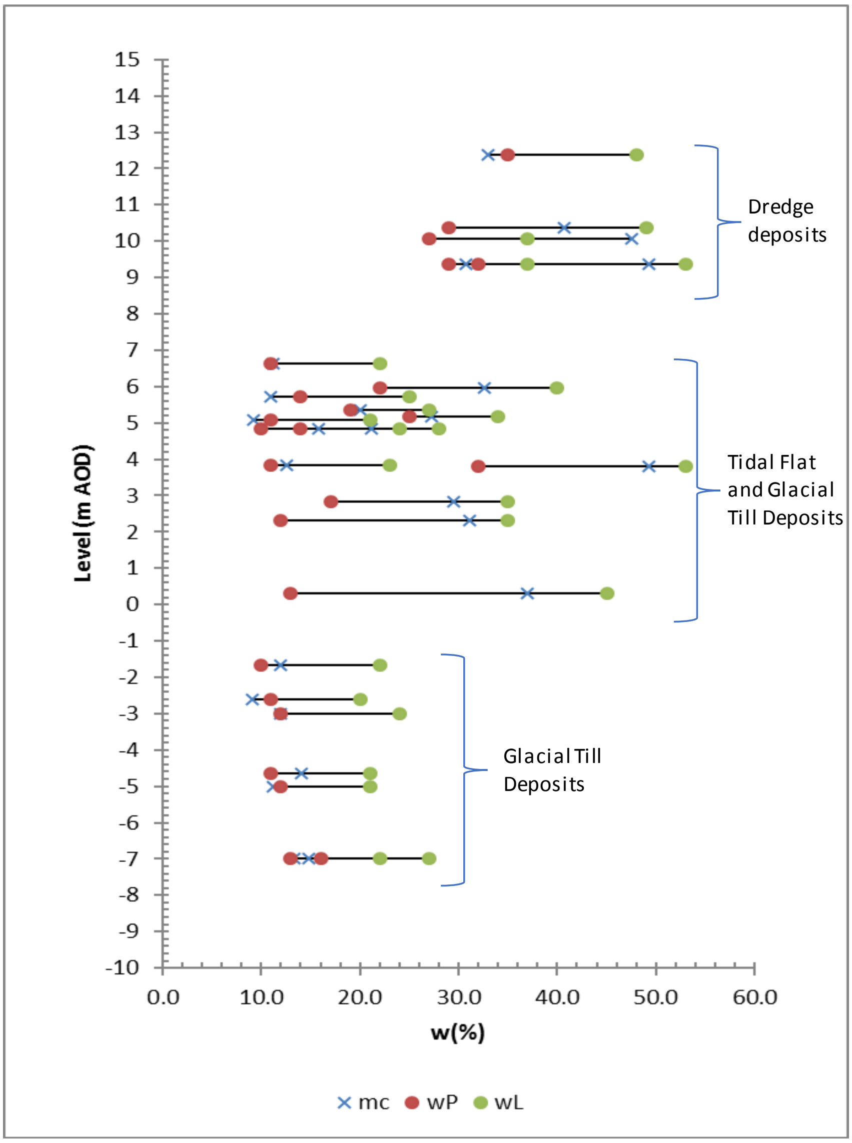
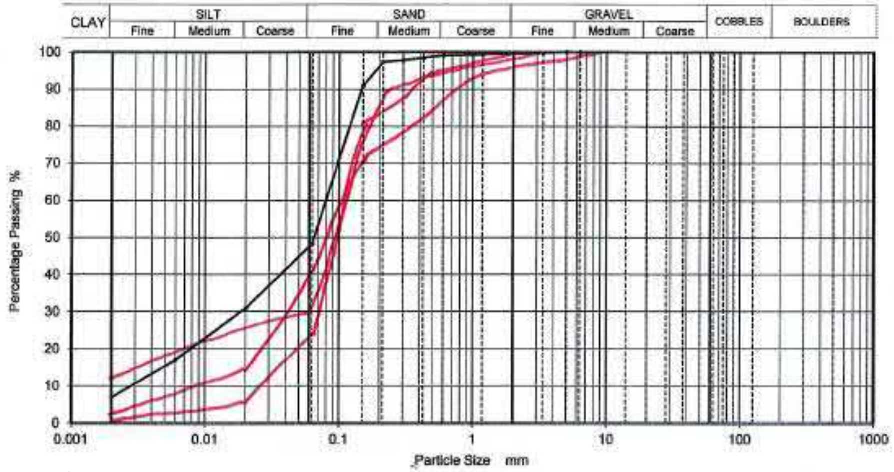
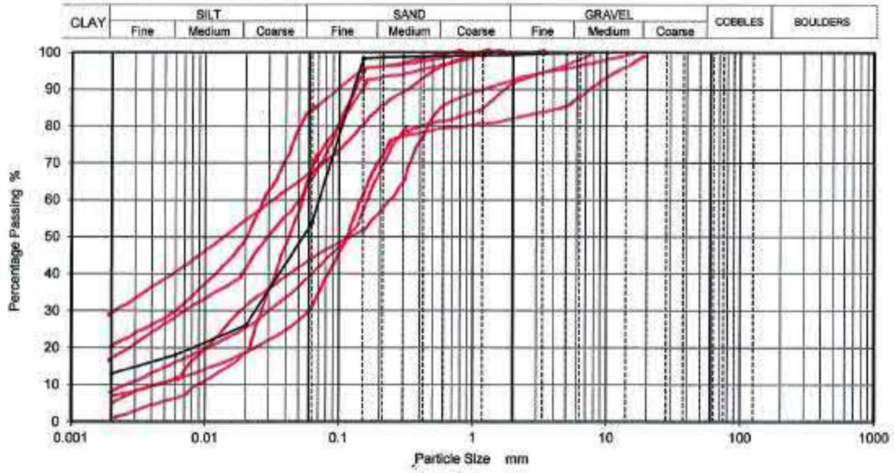


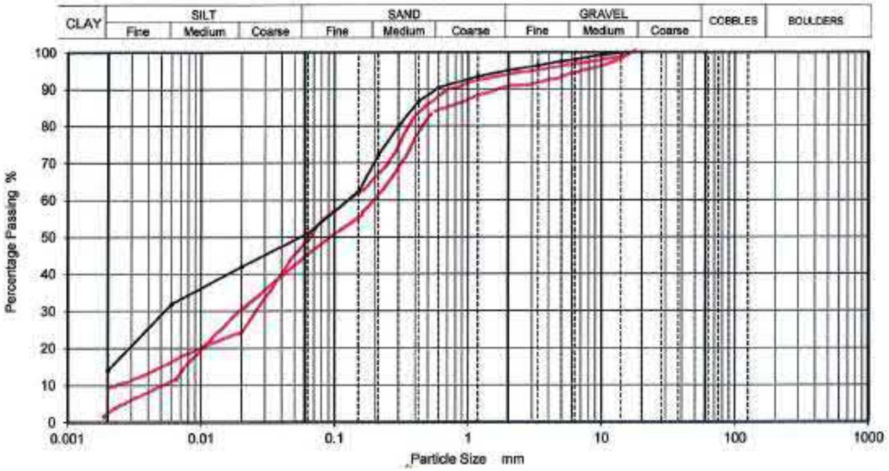
Figure A.3: Grading curves



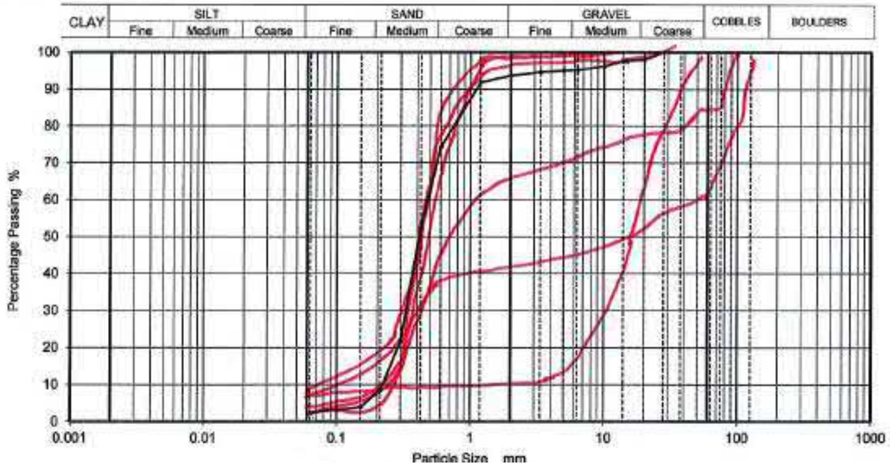
a) Dredge Deposits



b) Tidal Flat Deposits



c) Glacial Till



d) Glacio-Fluvial Deposits

Figure A.4: Rock coring data

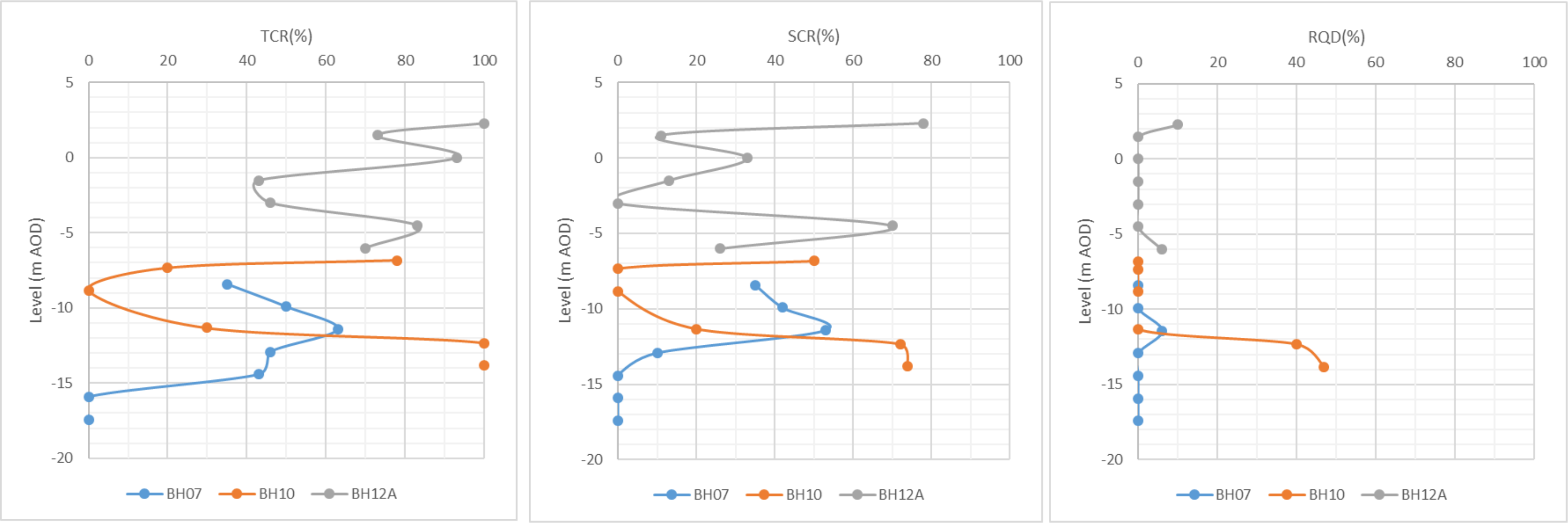


Figure A.5: Unconfined Compressive Strength (UCS) data

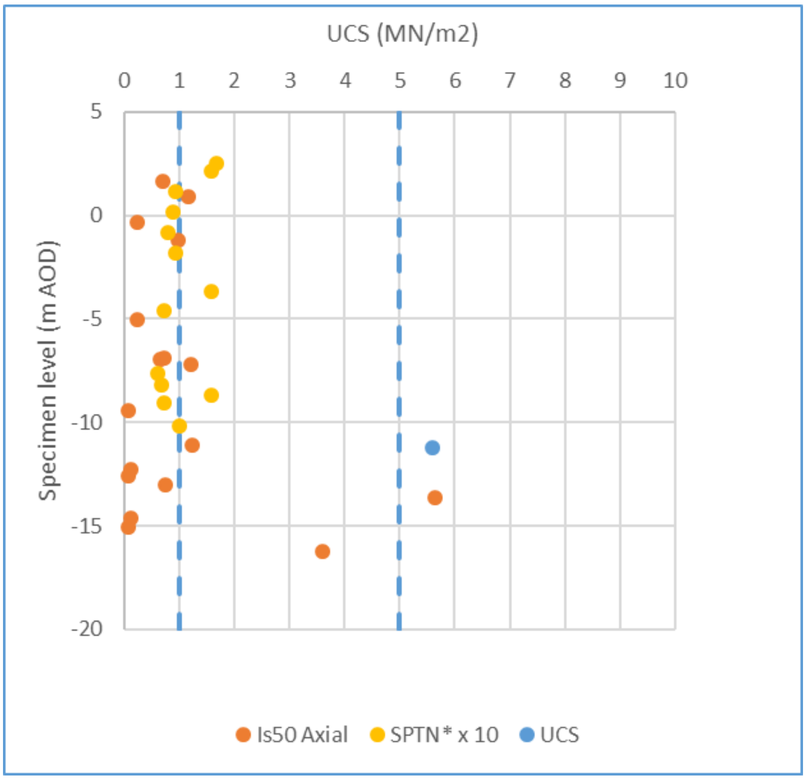


Figure A.6a: Undrained shear strength data BH03 and BH04/04A

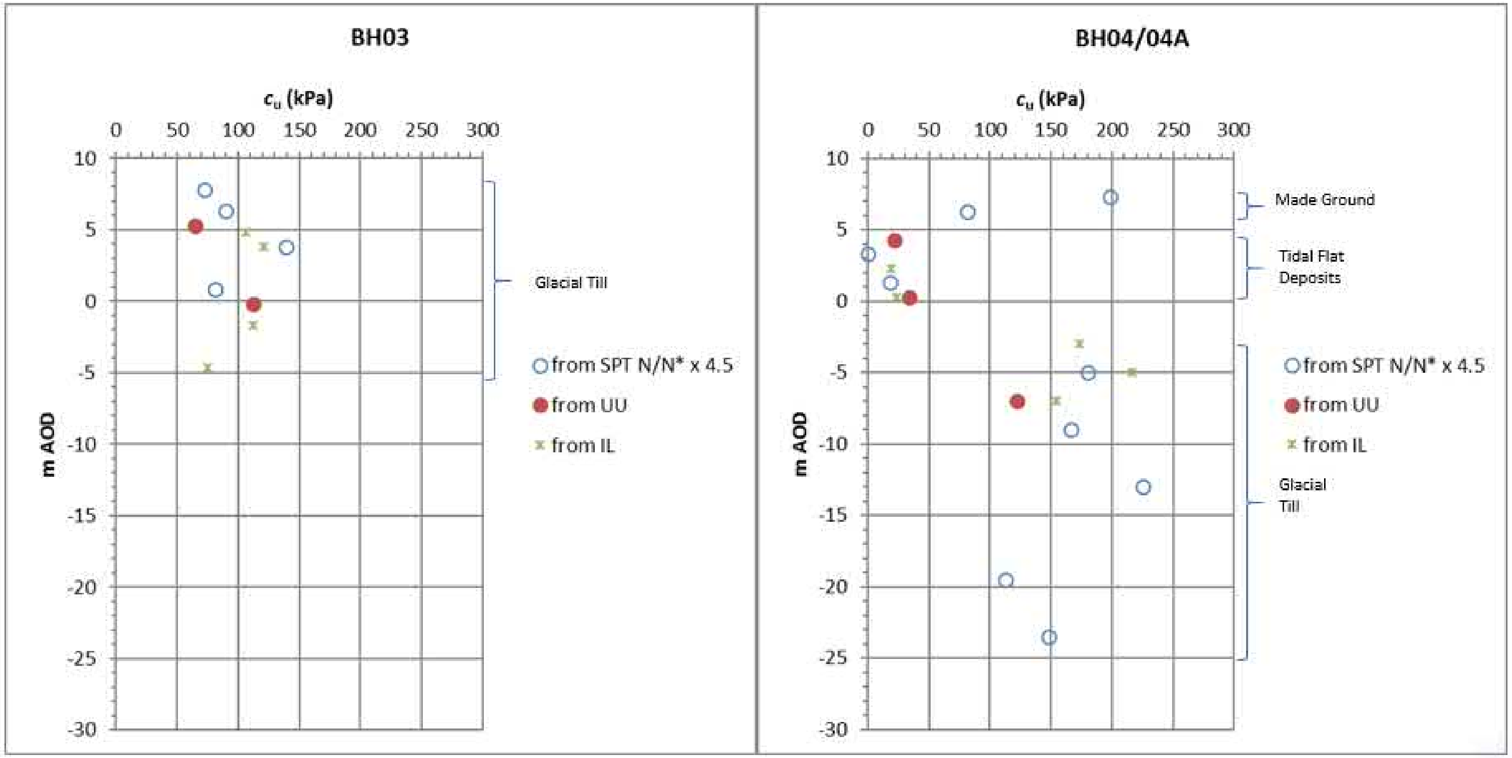


Figure A.6b: Undrained shear strength data BH05/05A and BH07

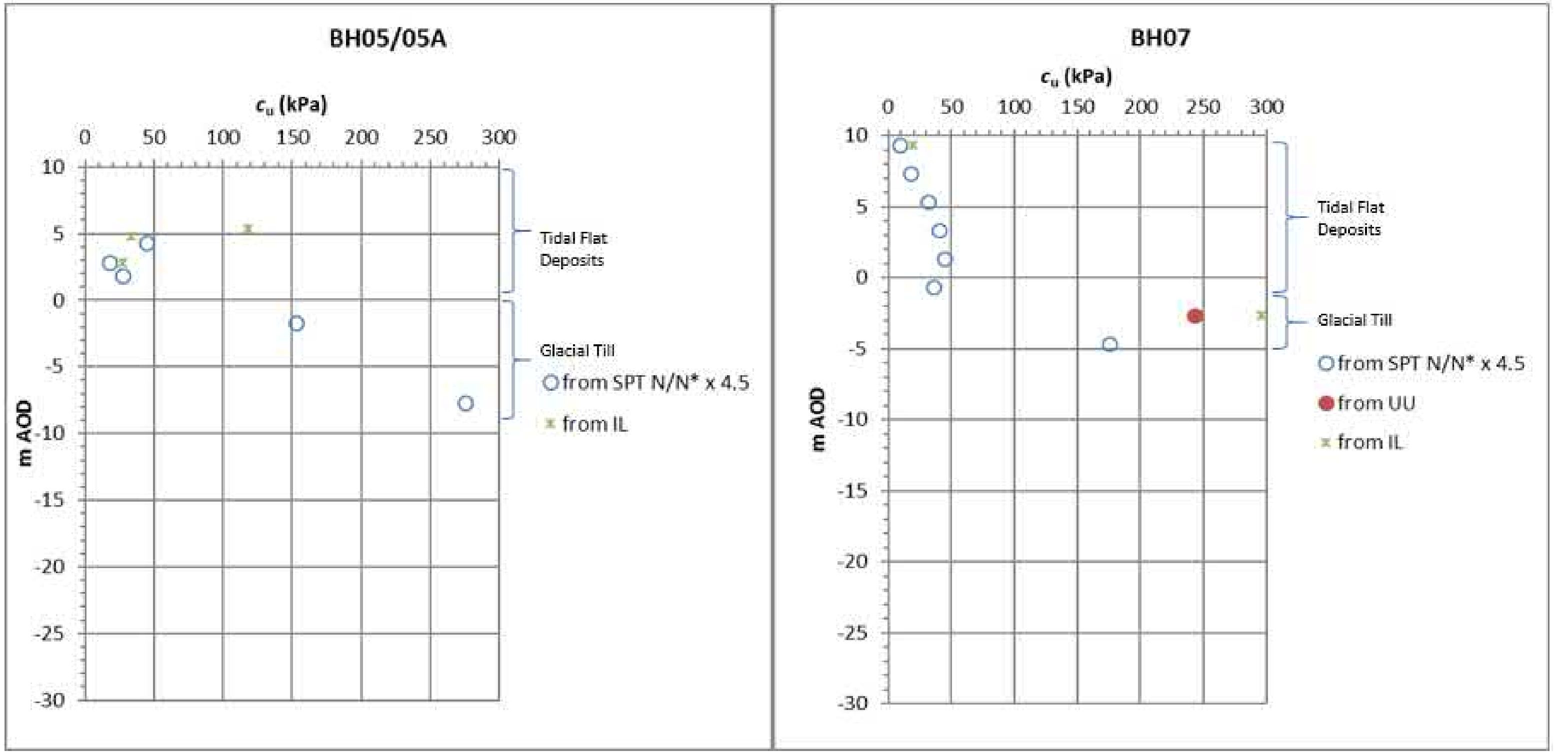


Figure A.6C: Undrained shear strength data BH06/06A BH10

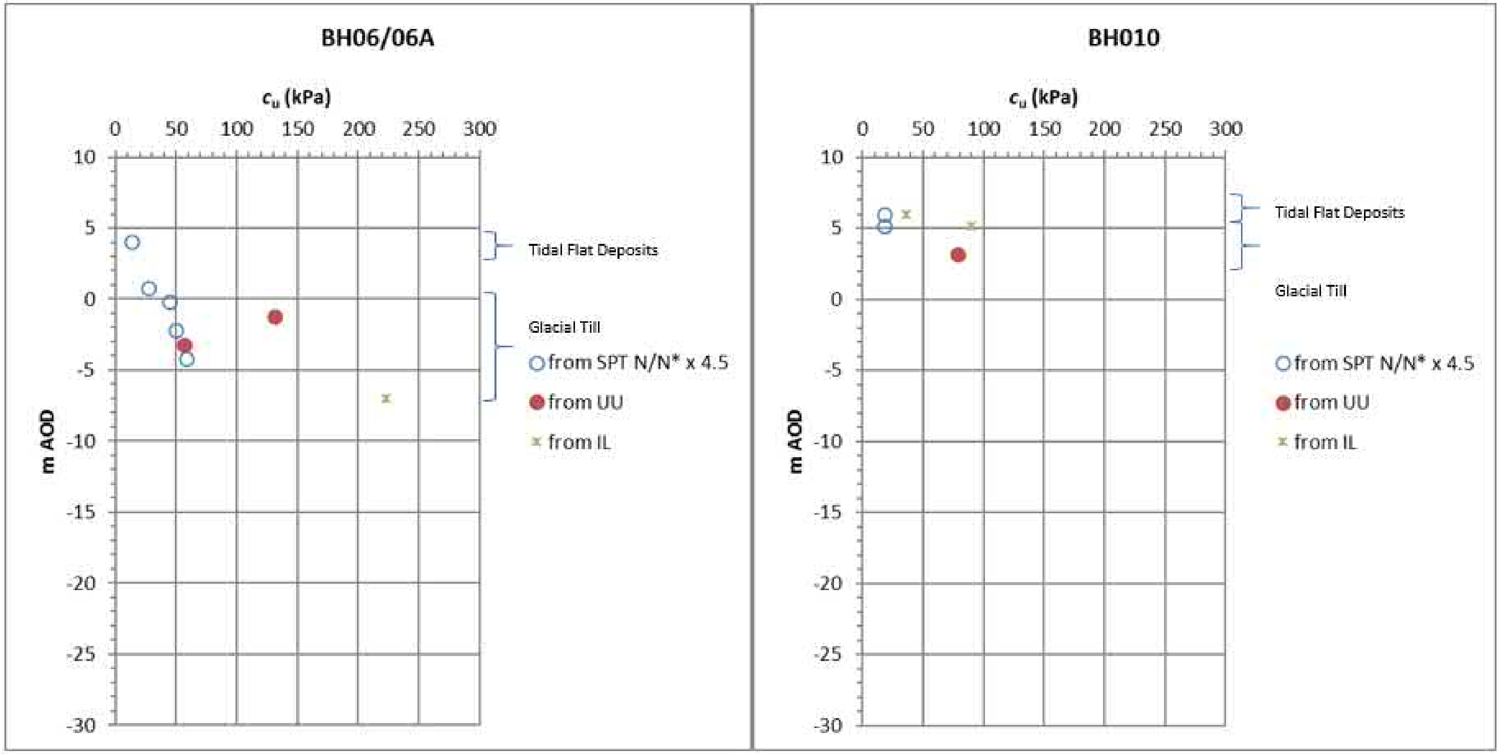
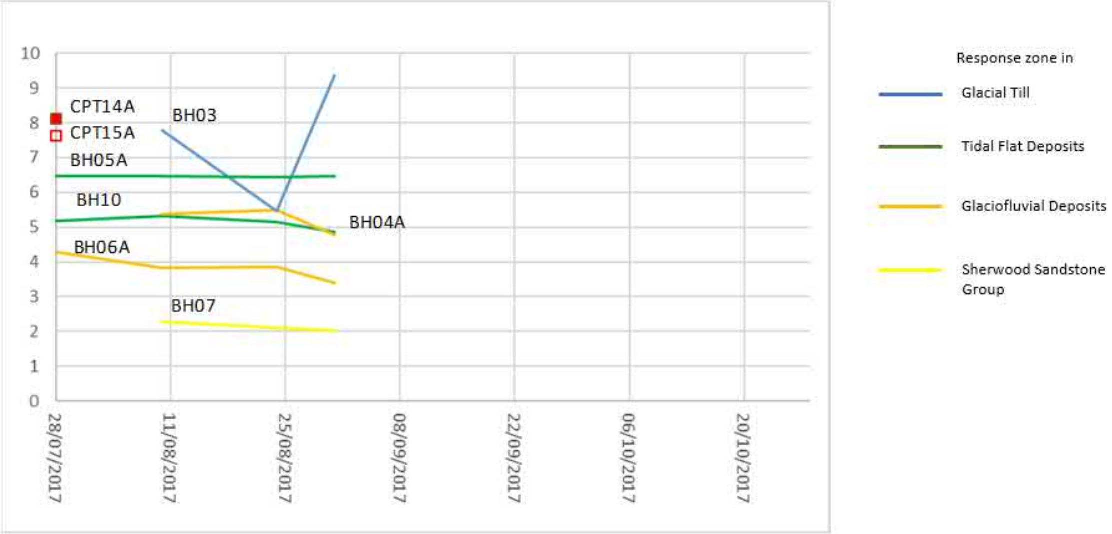
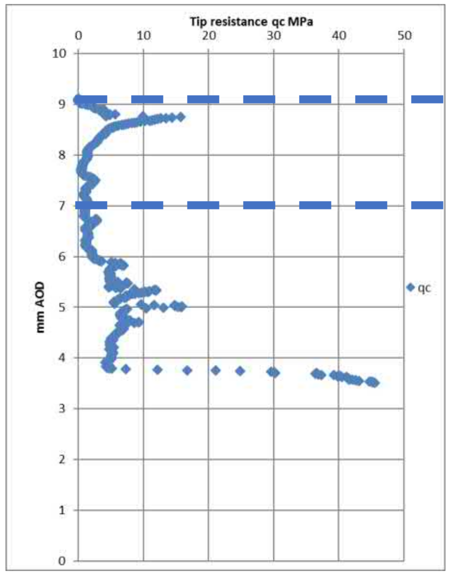
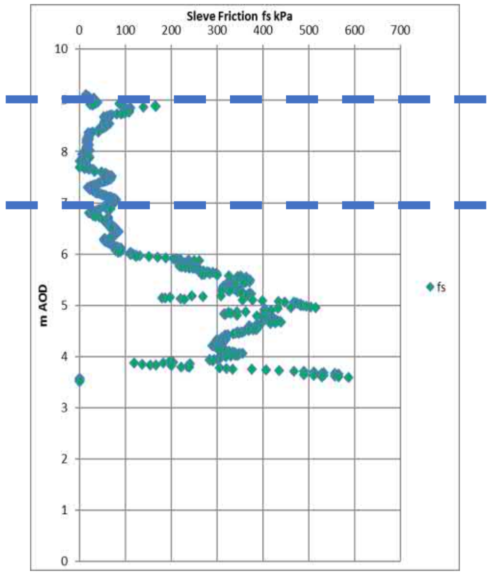


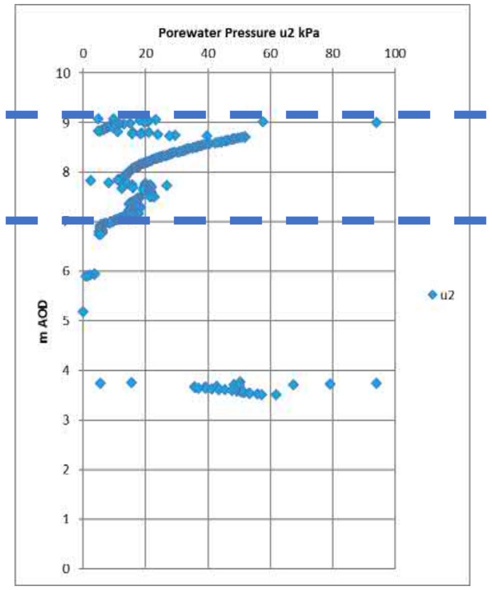
Figure A.7: Groundwater levels (mAOD)

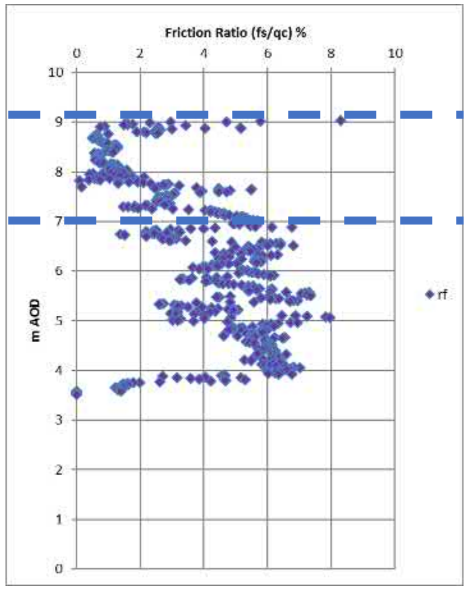


CPT01 Measured Parameters





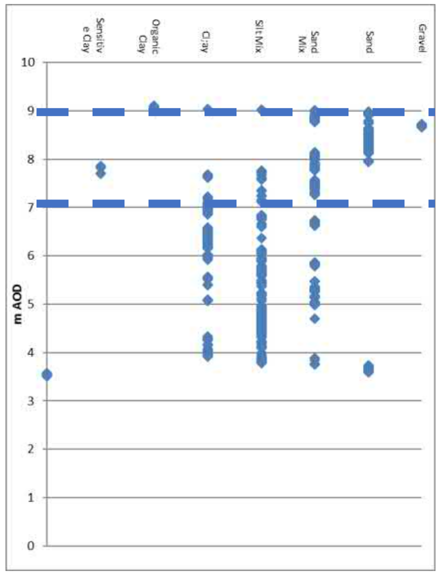




Made Ground

Glacial Till

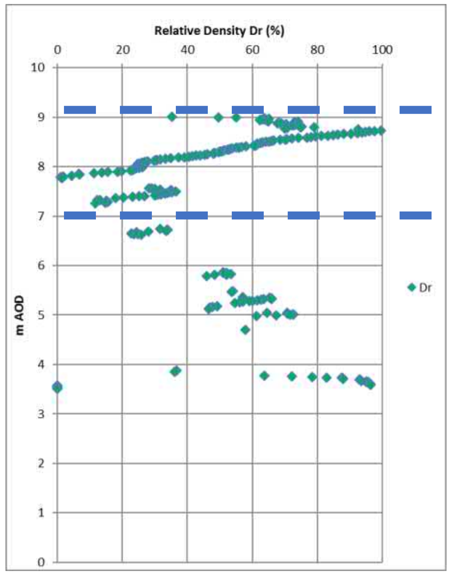
CPT01 Soil Behaviour Classes

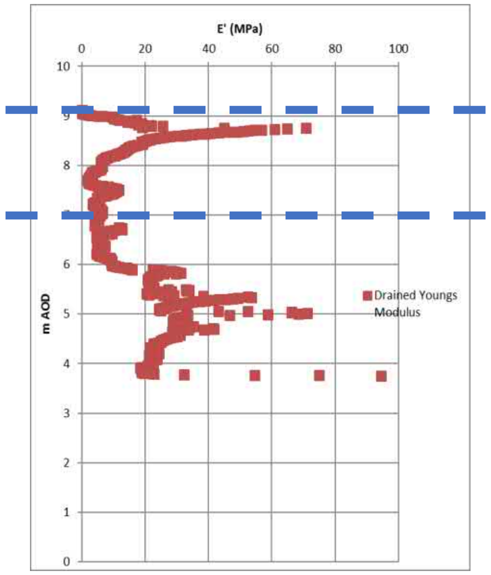


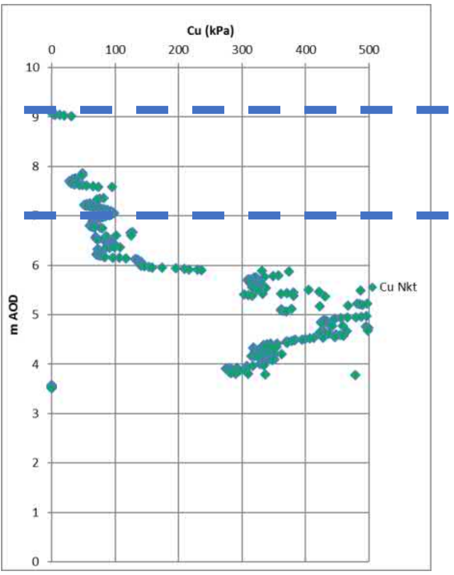
Made Ground

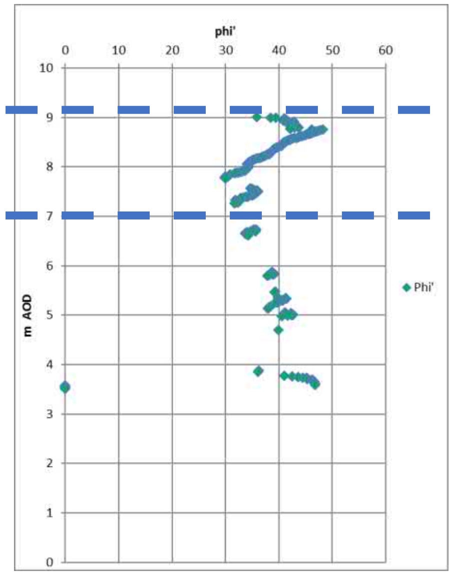
Glacial Till

CPT01 Derived Parameters





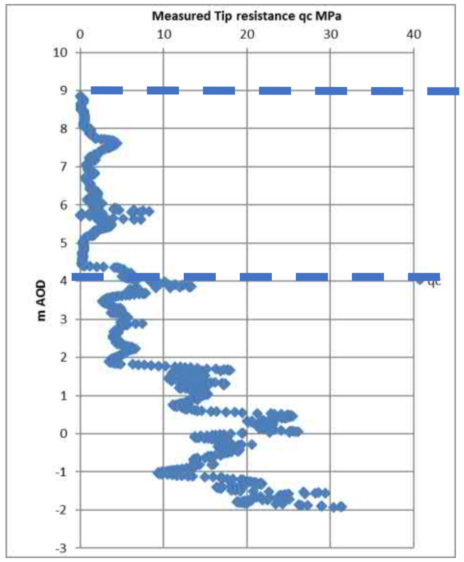


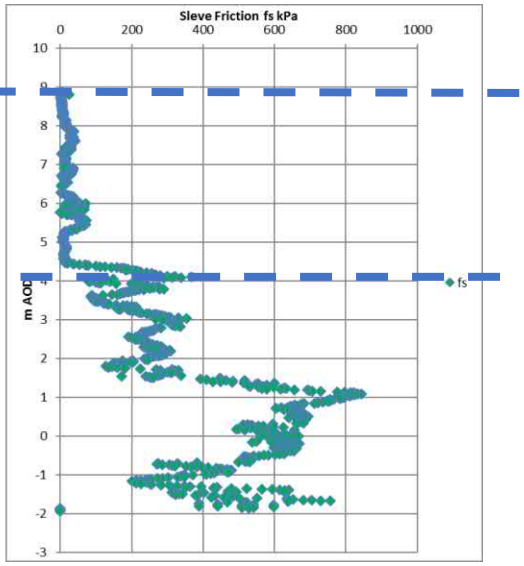


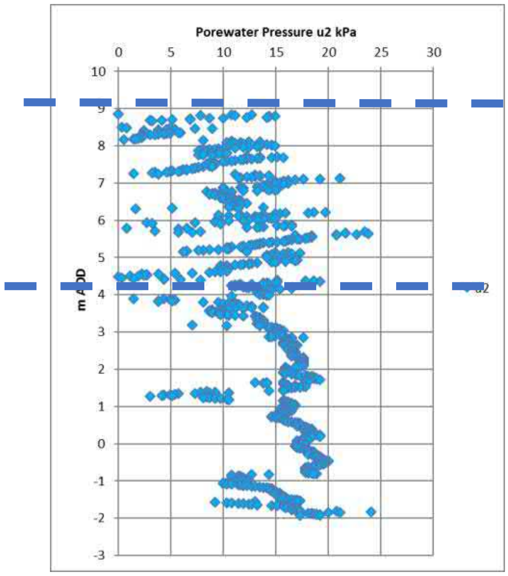
Made Ground

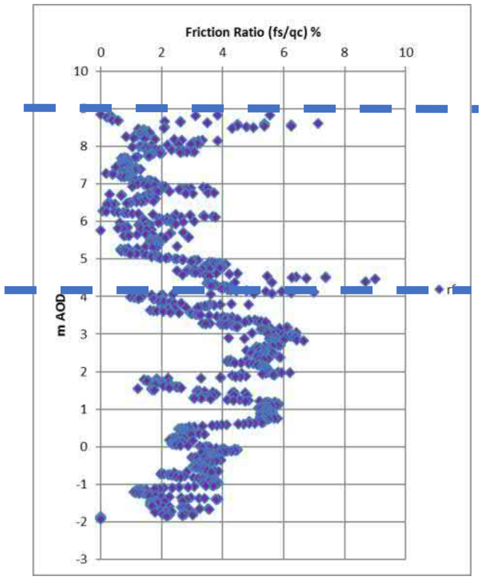
Glacial Till

CPT02 Measured Parameters





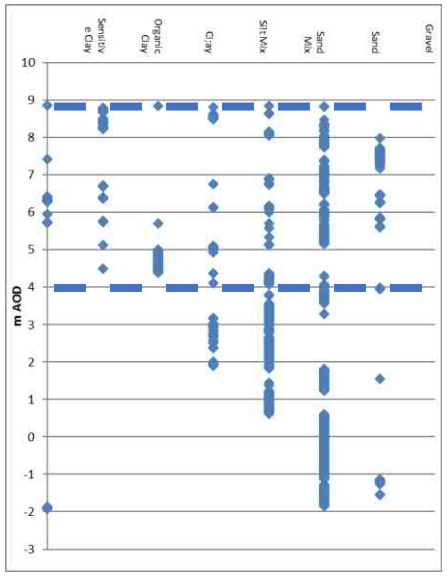




Made Ground

Glacial Till

CPT02 Soil Behaviour Classes



Made Ground

Glacial Till

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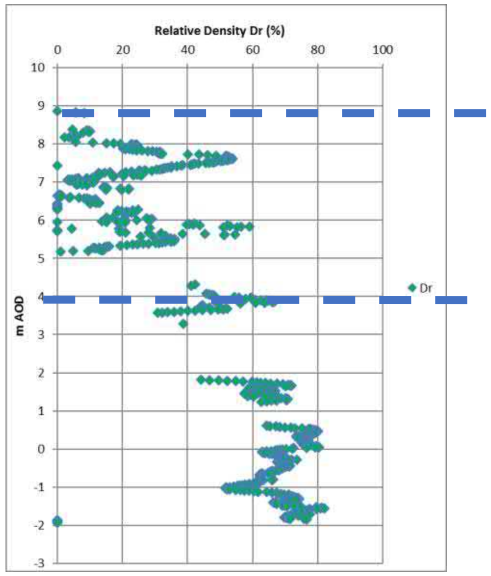
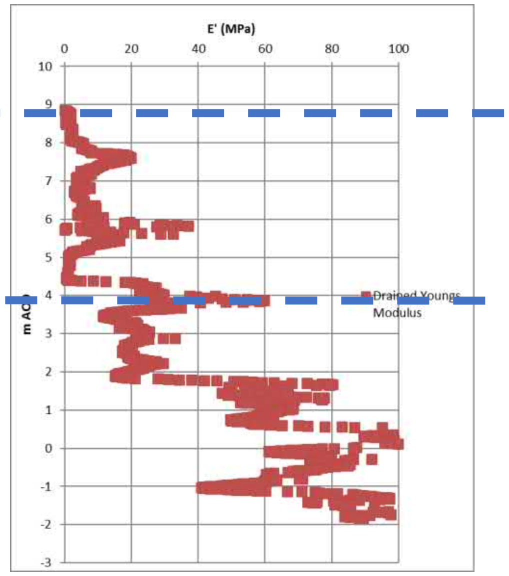
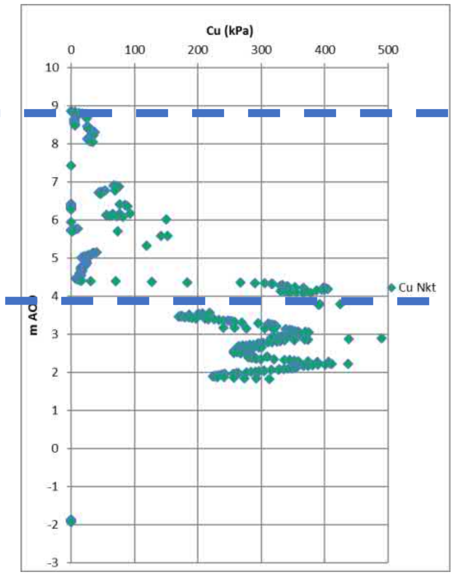
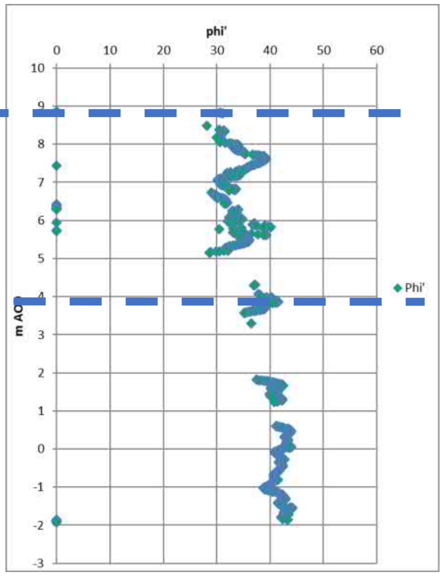




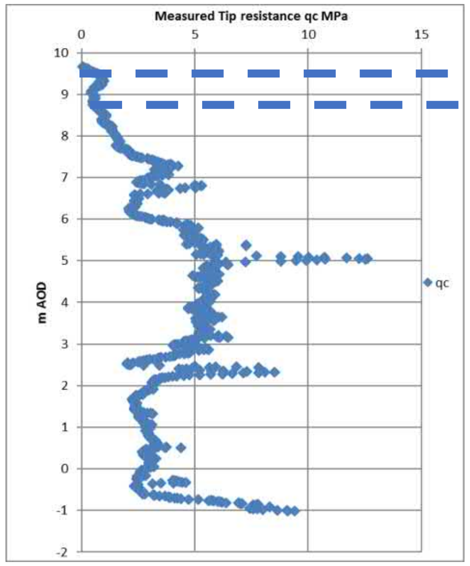


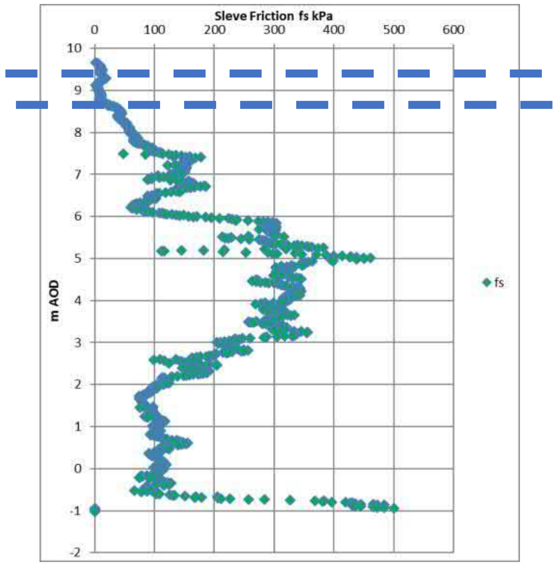


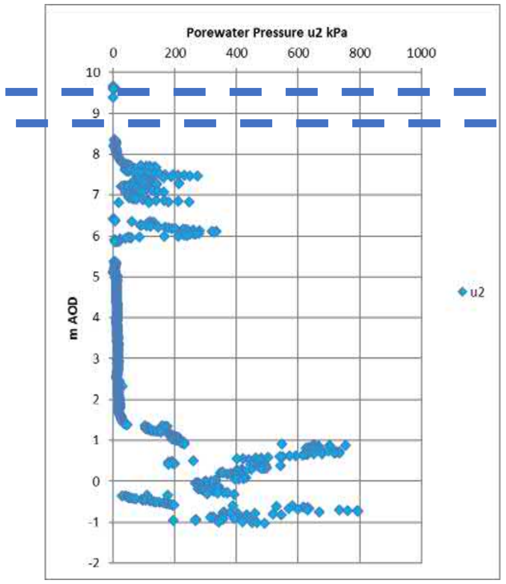
Made Ground

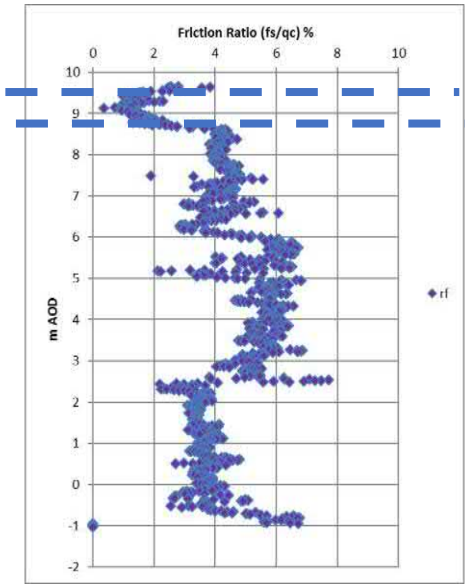
Glacial Till

CPT03 Measured Parameters





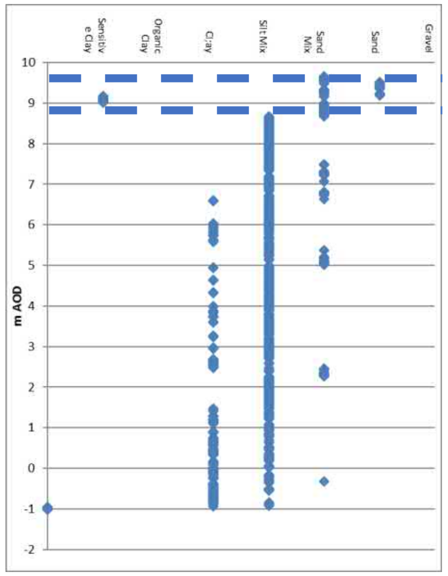




Made Ground

Glacial Till

CPT03 Soil Behaviour Classes



Made Ground

Glacial Till

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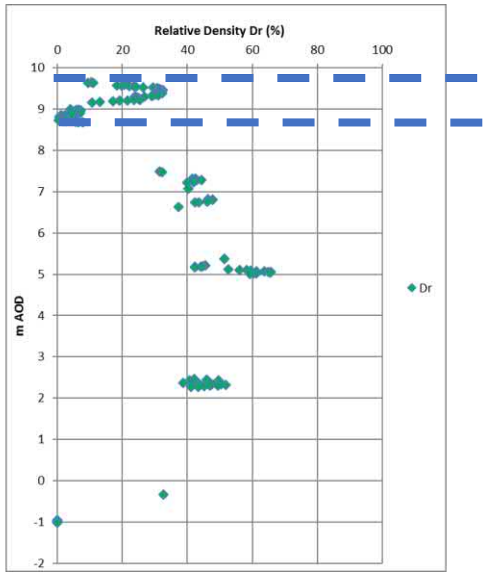
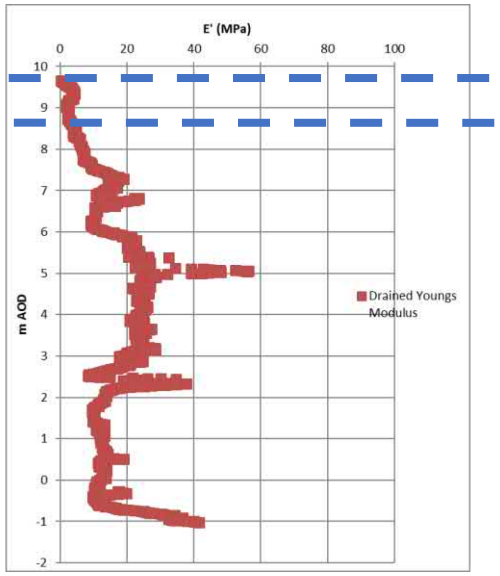
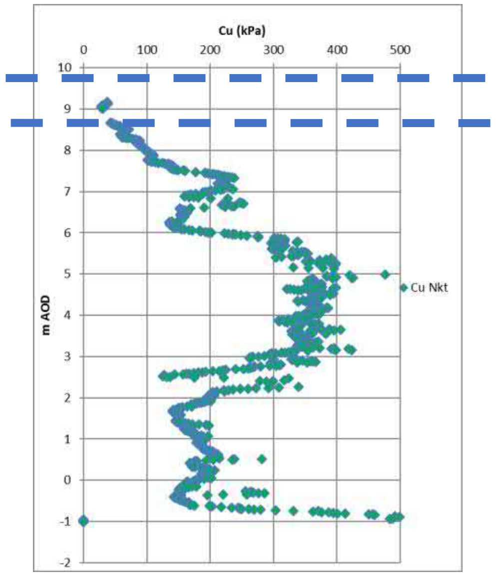
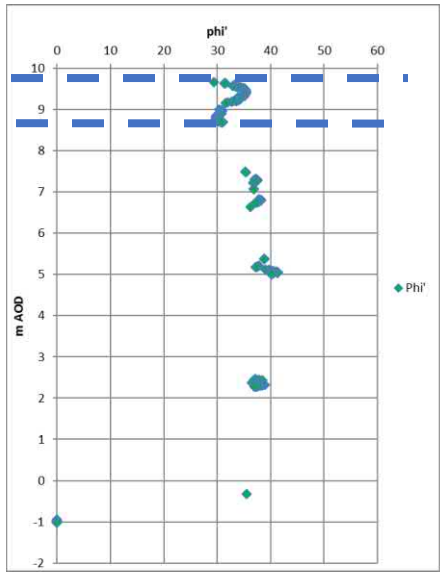




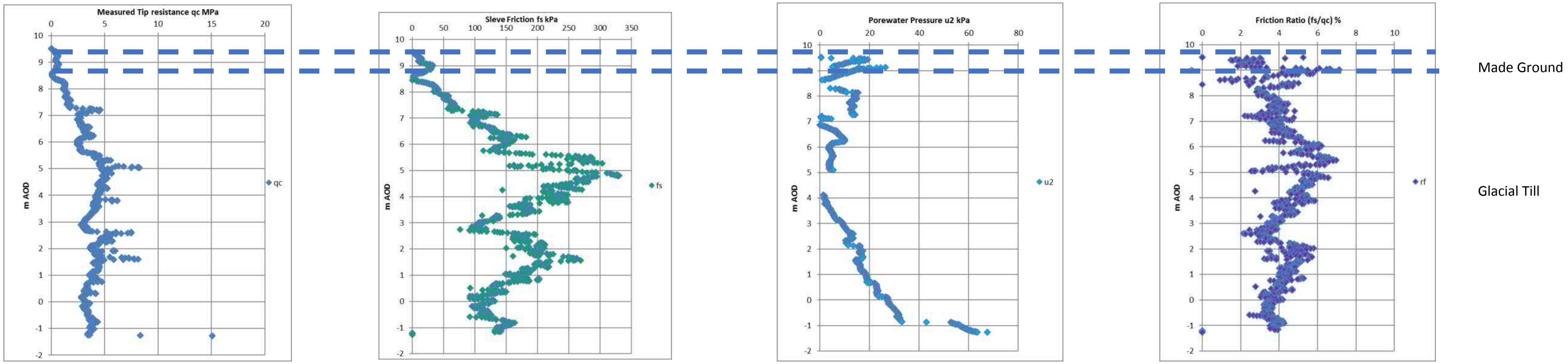




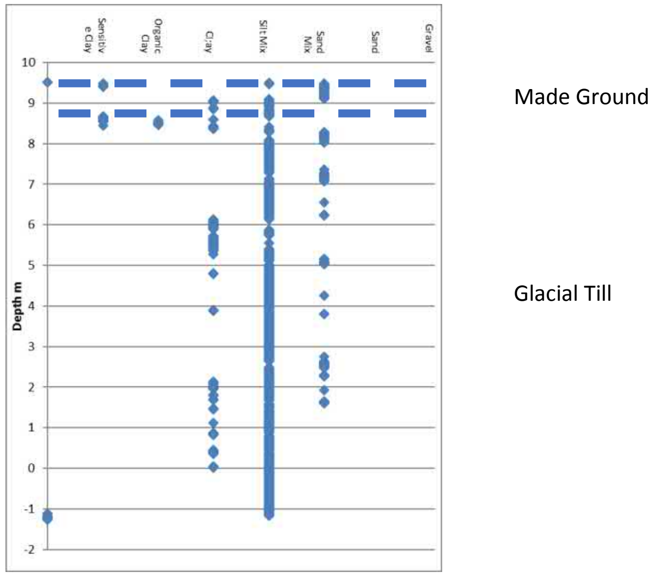
Made Ground

Glacial Till

CPT04 Measured Parameters



CPT04 Soil Behaviour Classes



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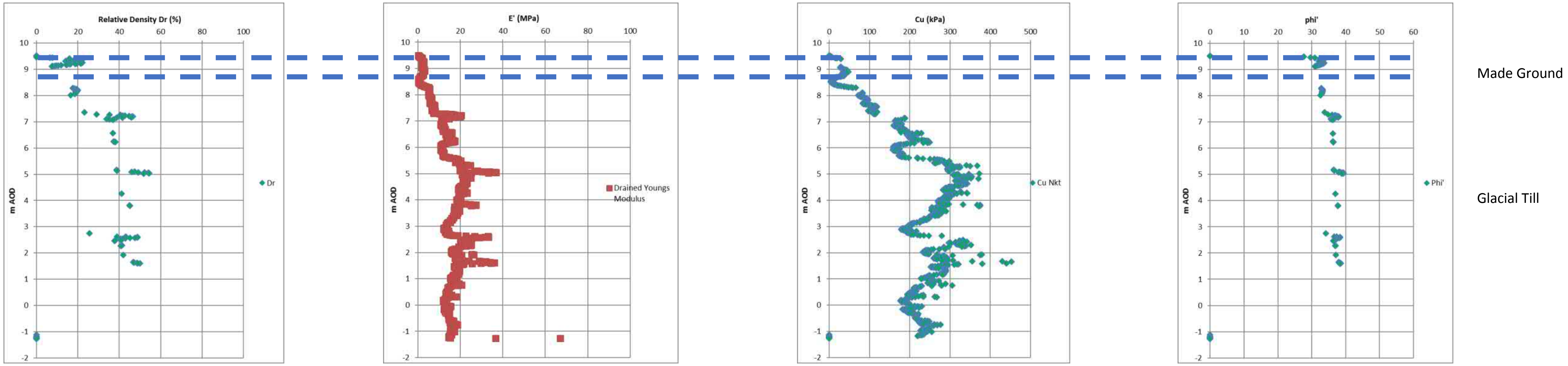
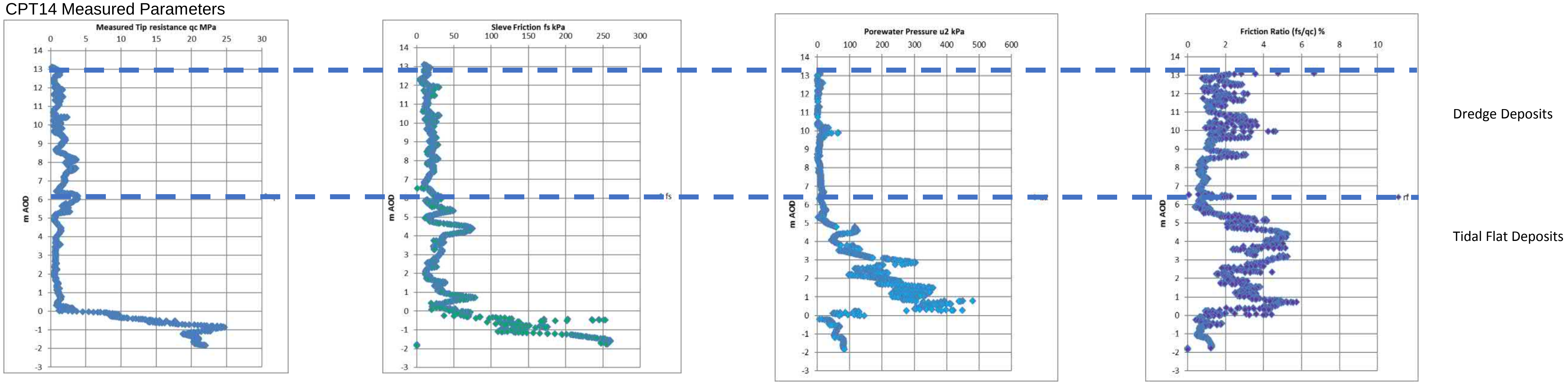


CPT14 Measured Parameters



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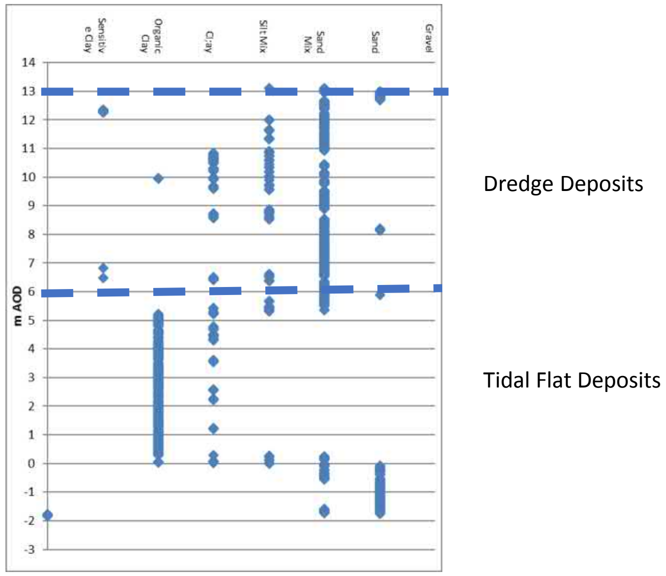
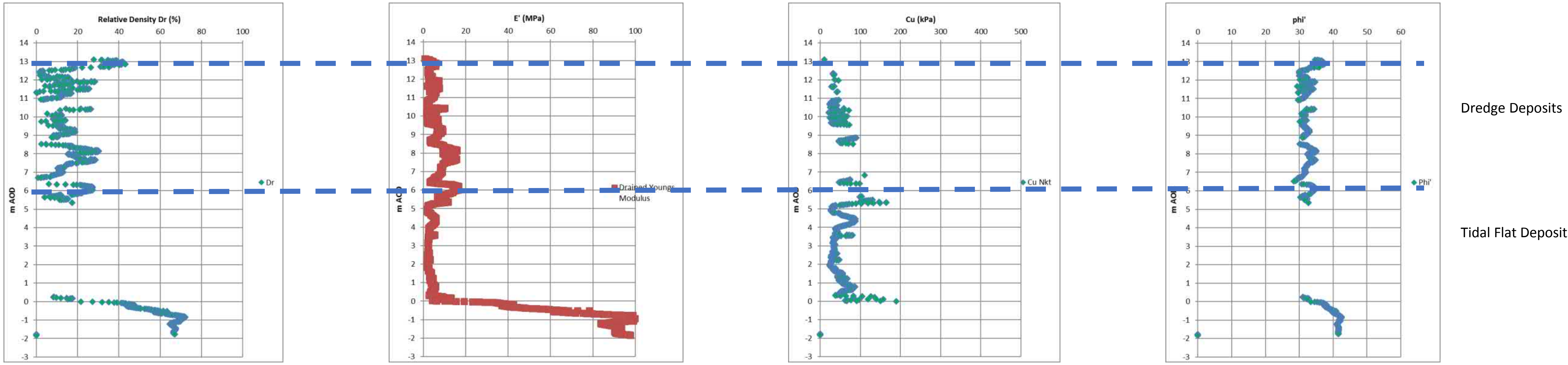


CPT014 Derived Parameters



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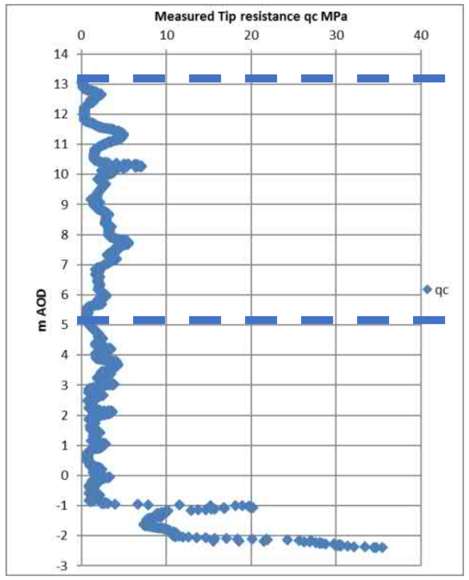
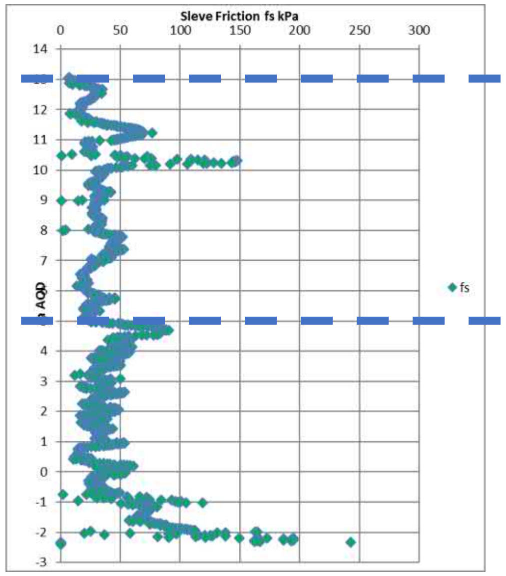
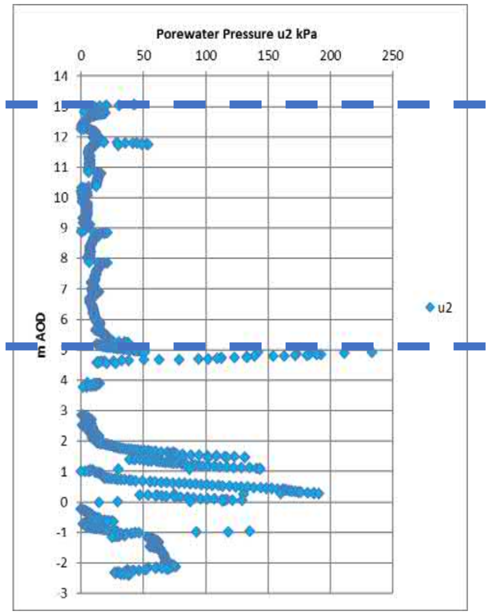
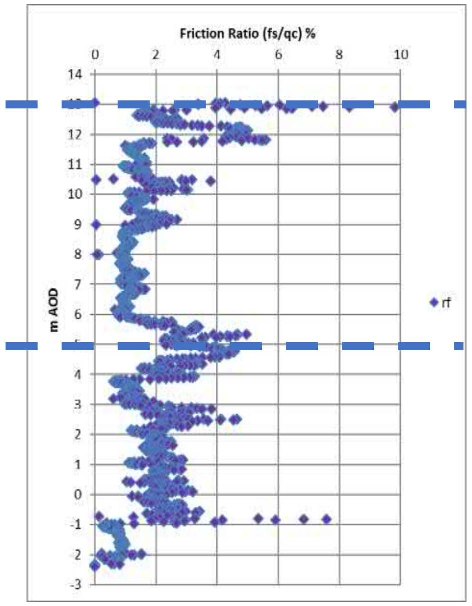




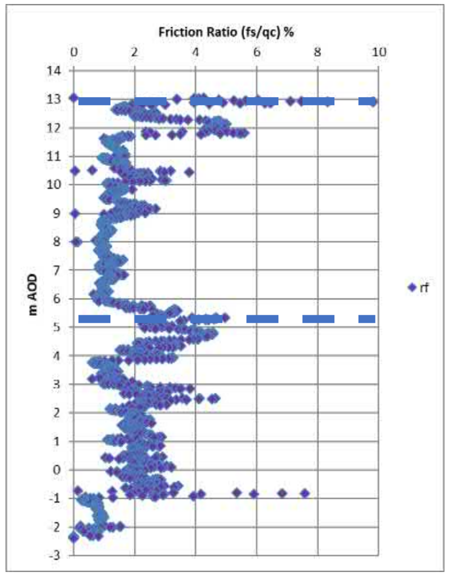




Dredge Deposits

Tidal Flat Deposits

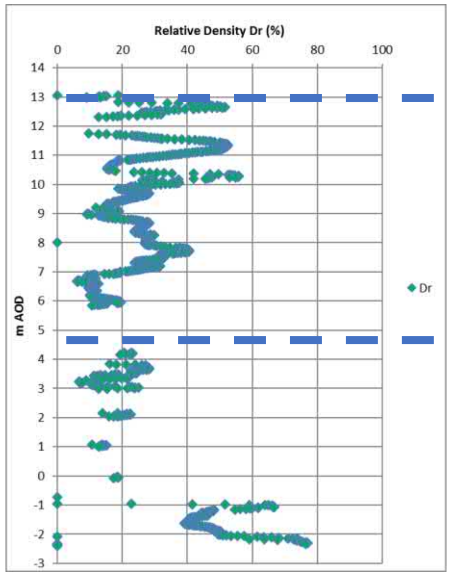
CPT15 Soil Behaviour Classes

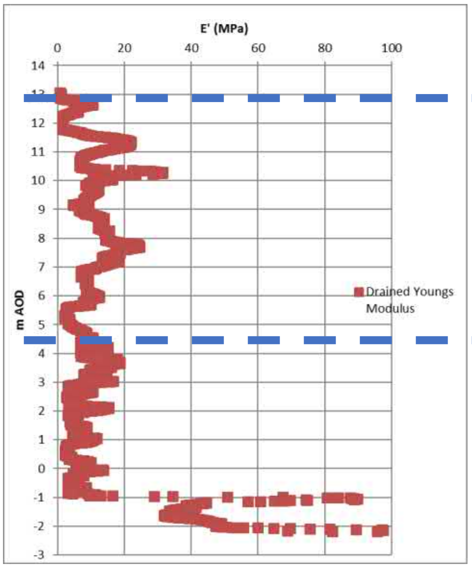


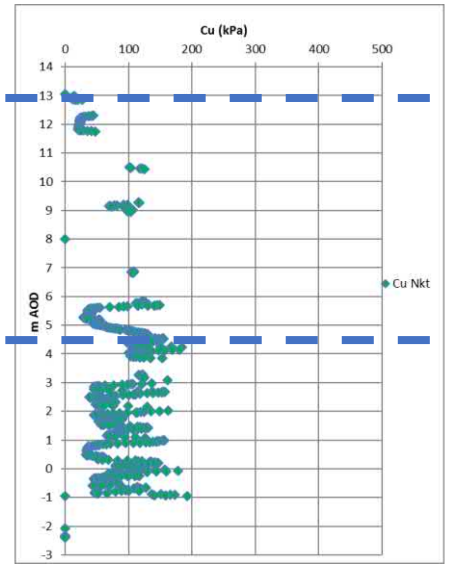
Dredge Deposits

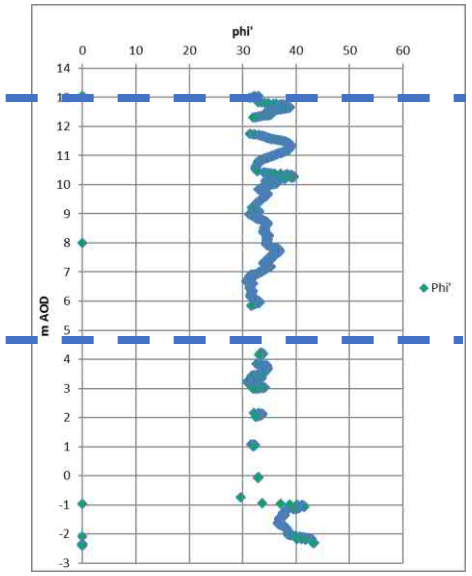
Tidal Flat Deposits

CPT15 Derived Parameters





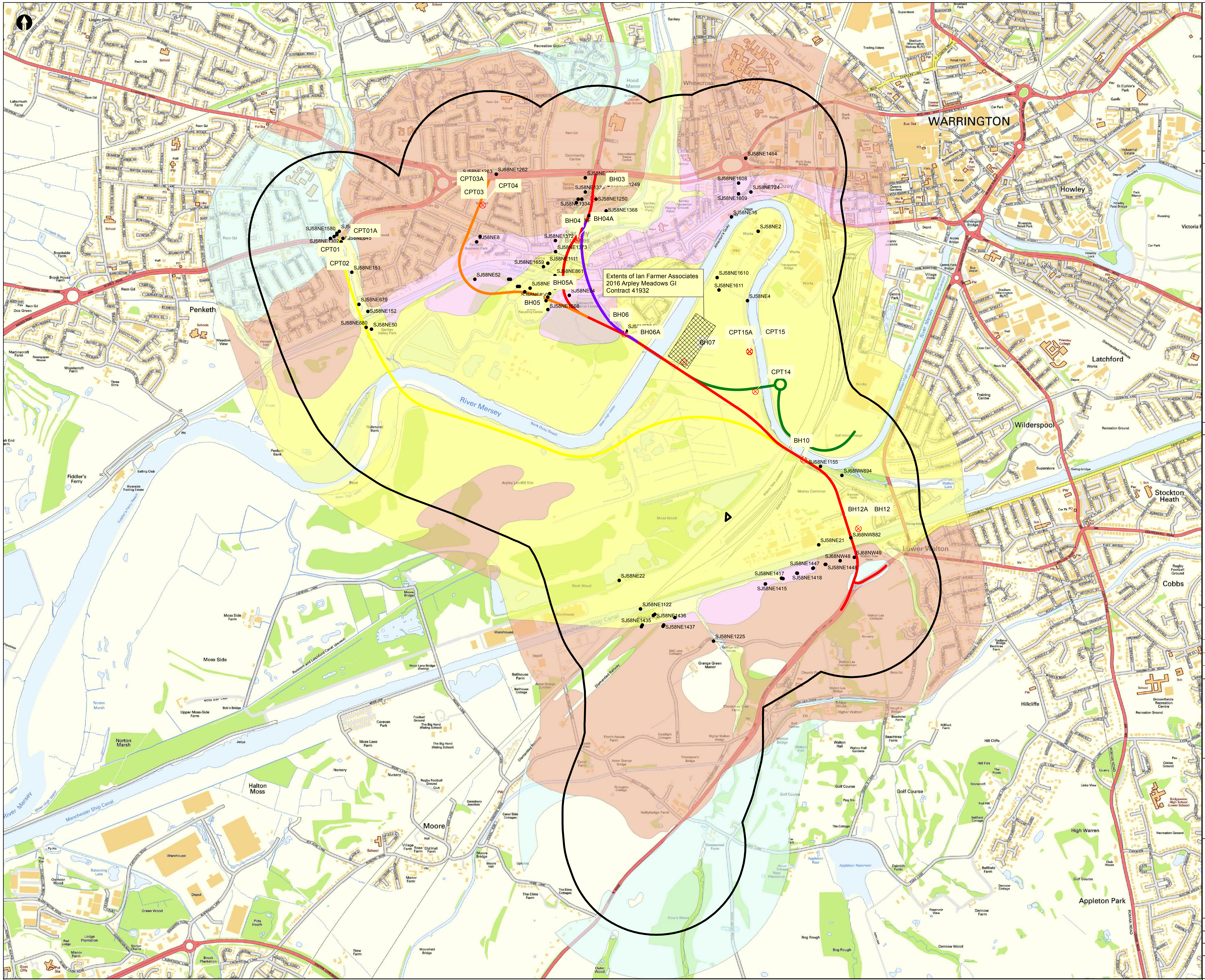




Dredge Deposits

Tidal Flat Deposits

B. Drawings



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 Drawing Western Link Route Options: Short List WL-MMD-07-SK-ZZ-T003-S0 (13 June 2017).

Key to Symbols

⊗	Western Link 2017 GI Location
●	BGS Borehole
▭	Study Area

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
02	27/09/2017	AC	For Information	NAH	NAH
01	25/04/2017	AC	For Information	NAH	NAH

MOTT MACDONALD

Spring Bank House,
33 Stamford Street,
Altrincham,
WA14 1ES

T: +44 (0) 161 926400
W: mottmac.com

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	P02

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

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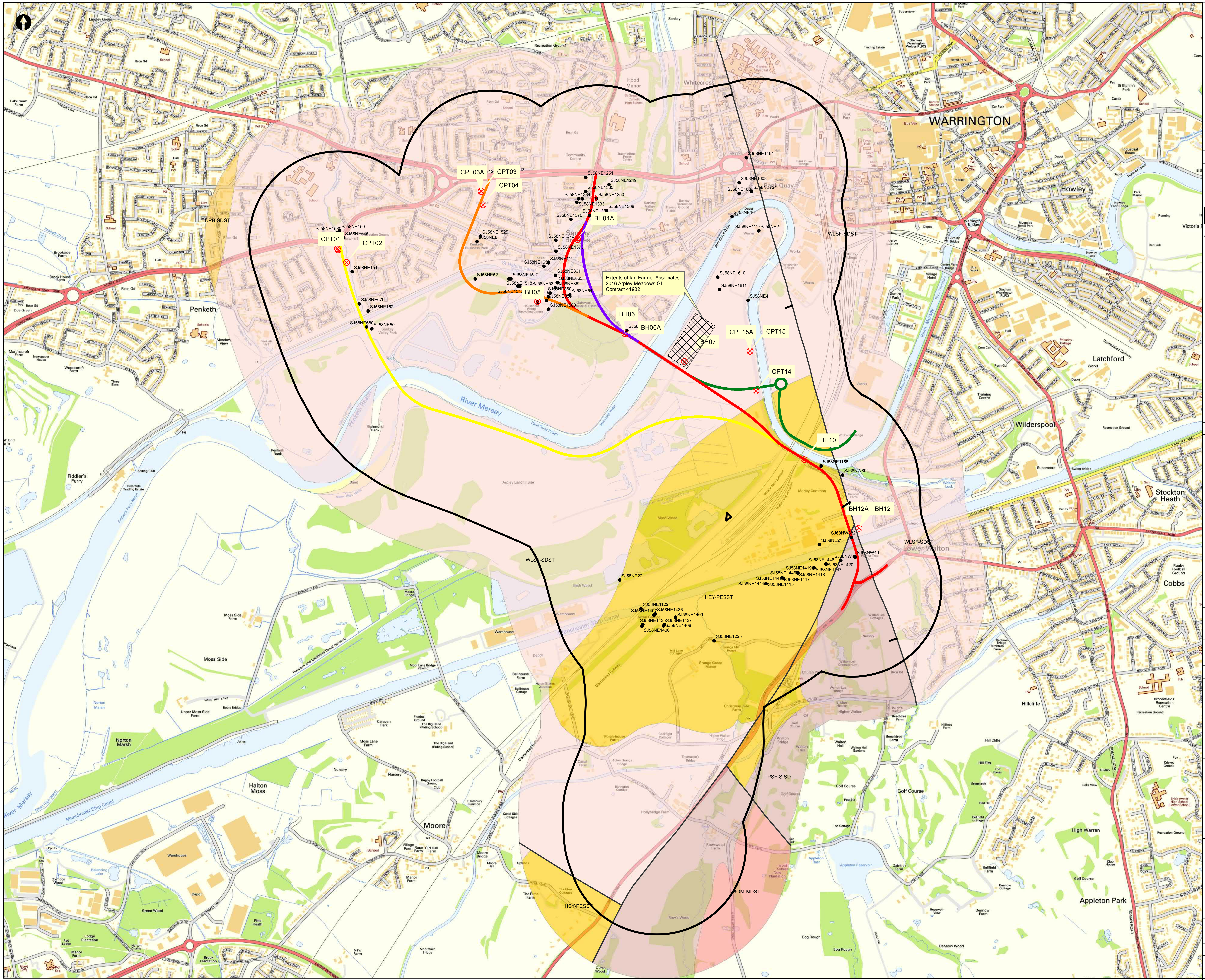
0 250 500 750 1,000 Metres

Superfical geology(A1 Version) final P2 Oct 18, 2017 - 04:49PM pic54635



02	27/09/2017	AC	For Information	NAH	NAH
01	25/04/2017	AC	For Information	NAH	NAH
Rev	Date	Drawn	Description	Ch'k'd	App'd

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 Drawing Western Link Route Options: Short List WL-MMD-07-SK-ZZ-T003-S0 (13 June 2017).

Key to Symbols

⊗	Western Link 2017 GI Location
●	BGS Borehole
▭	Study Area
—	Geological Fault Line (dash indicates downthrow)

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)*

Reference drawings

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

MOTT MACDONALD

Spring Bank House,
33 Stamford Street,
Altrincham,
WA14 1ES

T: +44 (0) 161 926400
W: mottmac.com

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Title

Western Link
Solid Geology Plan

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

Scale at A1	Status	Rev
1:10,000	INF	P02

Drawing No.
382900-WL-MMD-07-ZZ-GS-N-0002

Metres
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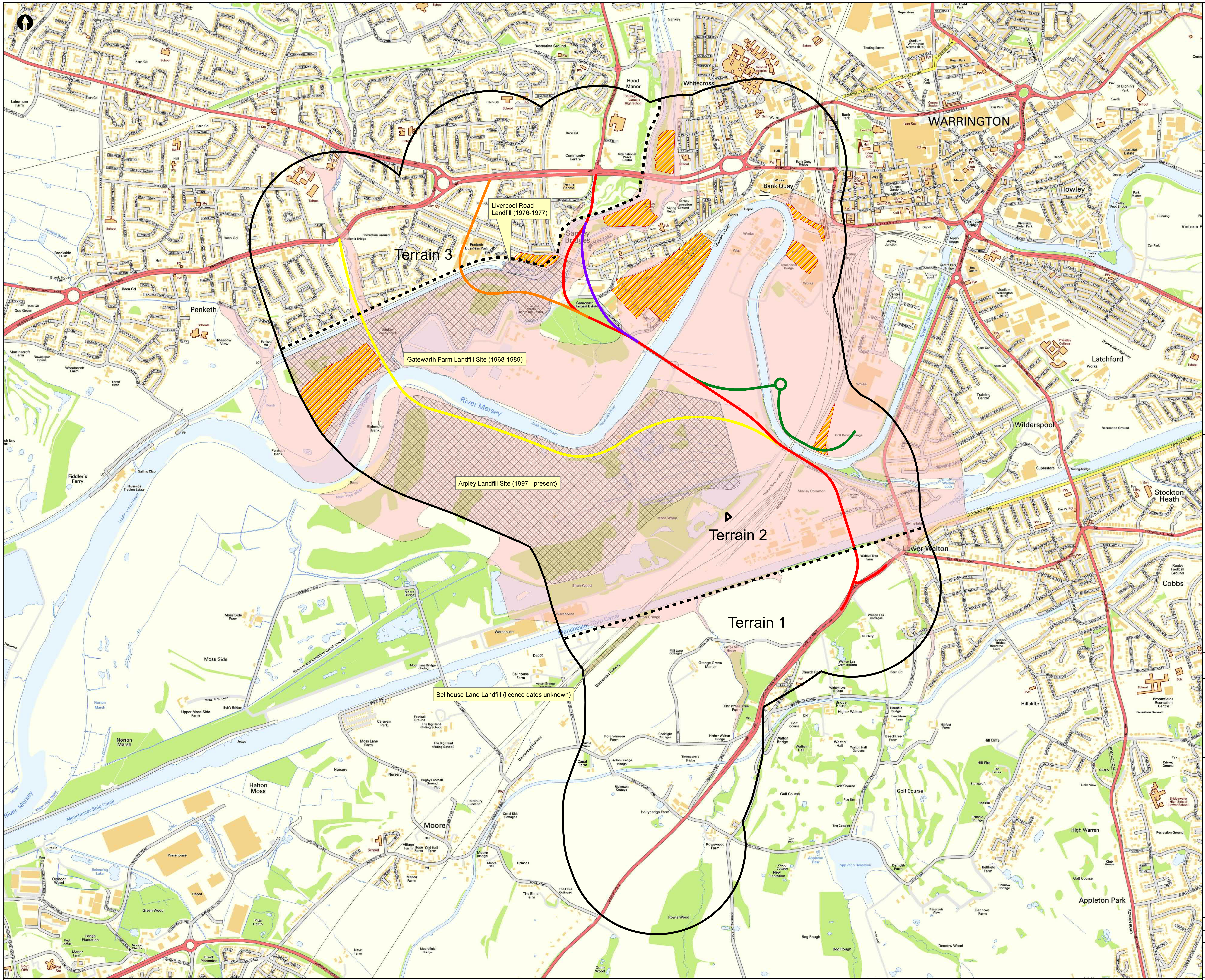

Liverpool Road Landfill (1976-1977)

Gatewarth Farm Landfill Site (1968-1989)

Arpley Landfill Site (1997 - present)

Bellhouse Lane Landfill (licence dates unknown)

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 Drawing Western Link Route Options: Short List WL-MMD-07-SK-ZZ-T003-S0 (13 June 2017).
3. The illustrated geotechnical constraints have been derived from the high level datasets described in 'Reference Drawings' below. Further 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
▨	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
02	27/09/2017	AC	For Information	NAH	NAH
01	25/04/2017	AC	For Information	NAH	NAH

MOTT MACDONALD

Spring Bank House,
33 Stamford Street,
Altrincham,
WA14 1ES

T: +44 (0) 161 926400
W: mottmac.com

Client

Warrington Borough Council

Title

Western Link
Geotechnical Constraints Plan

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

Scale at A1
1:10,000

Status
INF

Rev
P02

Drawing No.
382900-WL-MMD-07-ZZ-GS-N-0003

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Metres
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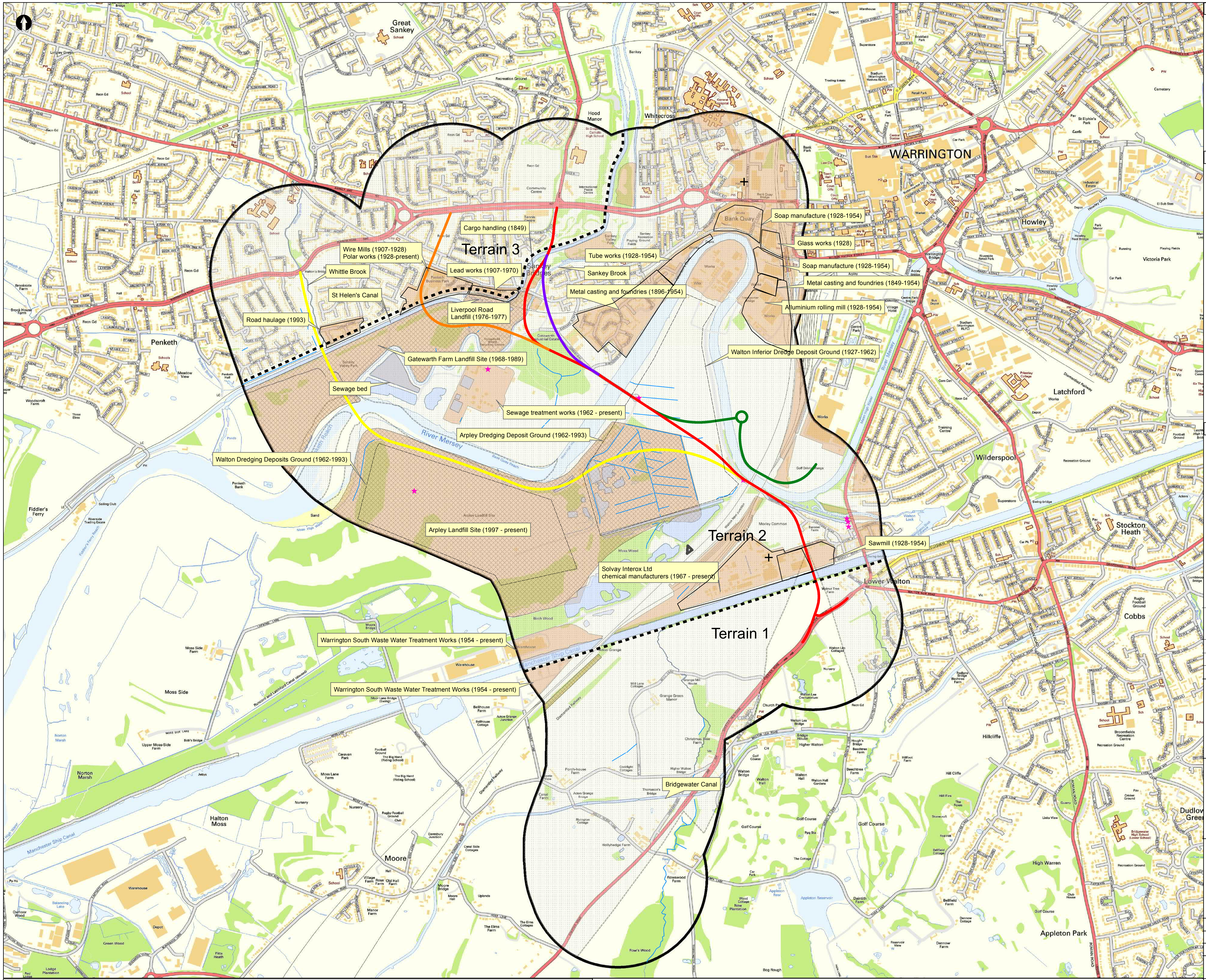
Geotechnical_Constraints(A1 Version) final P2 Oct 18, 2017 - 04:59PM pic54635



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 Drawing Western Link Route Options: Short List WL-MMD-07-SK-ZZ-T003-S0 (13 June 2017).
3. The illustrated geo-environmental constraints have been derived from the high level datasets described in 'Reference Drawings' below.
Further instrusive ground investigation will be required to refine the risks in relation to site-specific ground conditions and engineering proposals.

Key to Symbols

+	COMAH Site
★	Pollution Incident
🟦	Surface Water
🟧	Potentially Contaminated Land
▨	Principal Aquifer
▨	Landfill
▭	Study Area

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
02	27/09/2017	AC	For Information	NAH	NAH
01	25/04/2017	AC	For Information	NAH	NAH

MOTT MACDONALD

Spring Bank House,
33 Stamford Street,
Altrincham,
WA14 1ES

T: +44 (0) 161 926400
W: mottmac.com

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Warrington Borough Council

Title

Western Link
Geo-environmental Constraints Plan

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

Scale at A1	Status	Rev
1:10,000	INF	PO2

Drawing No.
382900-WL-MMD-07-ZZ-GS-N-0004

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Contains Ordnance Survey data (c) Crown copyright and database right 2017

0 250 500 750 1,000 Metres

Geoenvironmental_Constraints(A1 Version) final P2 Oct 18, 2017 - 04:55PM pic54635

Level Datum =-40.000

PROPOSED LEVELS	EXISTING LEVELS	CHAINAGE
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21.141	19.189	100.000
22.391	17.520	150.000
23.859	16.718	200.000
26.306	15.866	250.000
28.299	15.147	300.000
29.458	13.596	350.000
29.783	4.923	400.000
29.276	8.995	450.000
27.935	8.979	500.000
25.760	9.443	550.000
22.861	8.931	600.000
19.861	9.118	650.000
16.861	8.096	700.000
13.861	7.754	750.000
10.861	7.461	800.000
7.936	6.760	850.000
5.994	6.564	900.000
5.302	7.539	950.000
5.313	6.619	1000.000
6.070	6.415	1050.000
6.627	7.138	1100.000
7.425	8.668	1150.000
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13.568	12.930	1300.000
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14.913	12.551	1450.000
14.422	12.616	1500.000
13.922	12.522	1550.000
13.422	12.012	1600.000
12.922	11.664	1650.000
12.422	11.702	1700.000
11.922	11.204	1750.000
11.605	11.288	1800.000
12.407	11.100	1850.000
14.240	11.611	1900.000
15.547	3.087	1950.000
16.019	3.214	2000.000
15.659	5.933	2050.000
14.465	6.220	2100.000
12.438	5.278	2150.000
9.880	5.396	2200.000
8.351	6.449	2250.000
8.060	6.360	2300.000
8.234	6.105	2350.000
8.447	6.631	2400.000
9.555	6.372	2450.000
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15.482	7.549	2600.000
16.031	5.042	2650.000
15.747	8.287	2700.000
14.831	6.624	2750.000
13.876	6.770	2800.000
12.726	7.121	2850.000
10.826	7.799	2900.000
9.508	8.189	2950.000
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10.514	9.130	3150.000
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9.739	9.716	3304.901

Horizontal Scale = 1:1000,Vertical Scale = 1:100

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Notes

1. Geological boundaries are extrapolated from a limited number of boreholes and are intended for visualization purposes only.
2. This drawing should be read in conjunction with MML Report *Western Link Ground Investigation Report* 382900-WL-MMD-07-ZZ-RP-N-0002.
3. Red route alignment from MML model 382900-MMD-07-XX-M2-D-0027 *Preferred Route - Red (16 August 2017)*
4. Red route vertical profile from MML model 382900-MMD-07-XX-M2-D-0036 *Preferred Route - Red Route Long Section (30 August 2017)*

Key to symbols

―	Vertical Highway Profile
▨	Dredge Deposits
🟥	Made Ground (Granular)
■	Made Ground (Cohesive)
🟨	Tidal Flat Deposits
🟧	Glaciofluvial Deposits
🟦	Glacial Till
🟨	Sherwood Sandstone Group

Reference drawings

1. 382900-MMD-07-XX-M2-D-0027 *Preferred Route - Red*
2. 382900-MMD-07-XX-M2-D-0036 *Preferred Route - Red Route Long Section*

Rev	Date	Drawn	Description	Ch'k'd	App'd
S2.1	09/10/2017	CD	First Issue	AC	NAH

MOTT MACDONALD

Spring Bank House
33 Stamford Street
Altrincham, WA14 1ES
United Kingdom

T +44 (0)161 926 4000
F +44 (0)161 926 4100
W www.mottmac.com

Client

WARRINGTON
Borough Council

Title

Western Link
Red Route Geological Long Section

Designed	A Carins	AC	Eng check	N Haynes	NAH
Drawn	C Dowson	CD	Coordination	A Carins	AC
Dwg check	A Carins	AC	Approved	N Haynes	NAH

Scale at A0	Status	Rev	Security
1:2000	S	2.1	STD

Drawing Number
WL-MMD-07-ZZ-CD-N-0012

C. WBC Data Search Arpley and Gatewarth Landfills

Data Review

Project title	Western Link, Project No. 382900
Subject	Warrington Borough Council landfill data review – Arpley Landfill & Gatewarth Landfill
Location	WBC Offices, 3rd Floor Room 15, New Town House, Buttermarket Street, Warrington, WA1 2NH
Date and time of meeting	31/05/2017 9:00am-3:30pm
Attendees	Chris Stanford – Mott MacDonald Angela Sykes – Warrington Borough Council EPO

Background

As part of the Western Link Stage 2 route option assessment, Mott MacDonald have undertaken a review of existing, publicly available electronic data files held by Warrington Borough Council (WBC) for Arpley Landfill Site and Gatewarth Farm Landfill site, shown in Figure 1 below.

The electronic data was viewed via a secure laptop at WBC offices, New Town House, Buttermarket Street, Warrington, WA1 2NH on 31st May 2017, following liaison with the WBC Environmental Protection Officer (EPO) Angela Sykes. In accordance with standard procedure and WBC policy, the USB ports on the laptop were disabled to prevent any copying of files, to ensure data protection and to preclude a breach of copyright regulations. The relevant data for each landfill site, in relation to the proposed Western Link route options is summarised below.

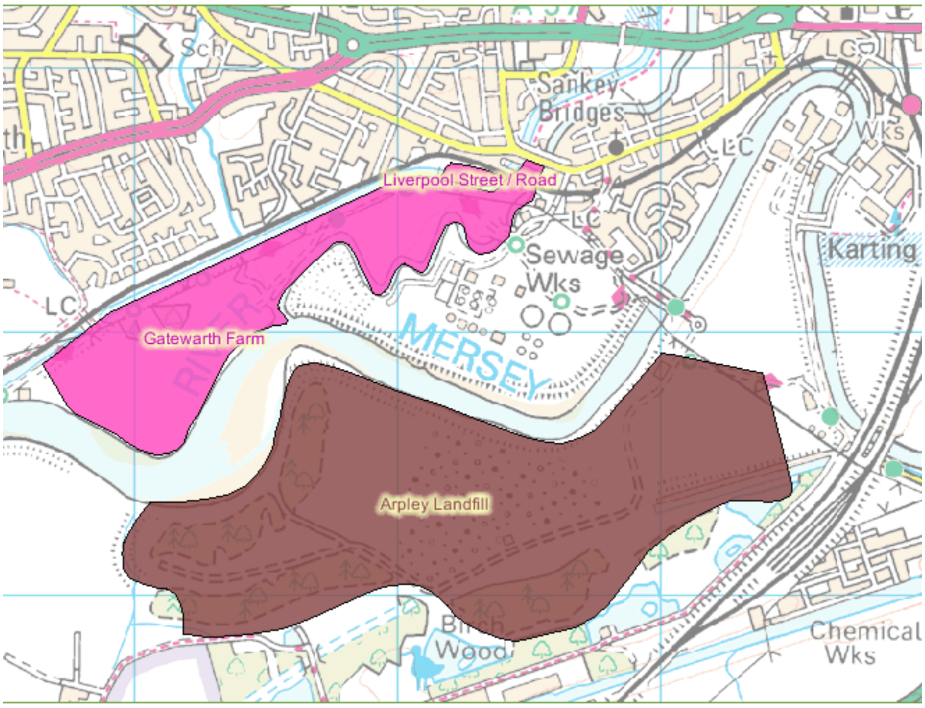


Figure 1 Location and boundary of Gatewarth Farm and Arpley Landfill (image source Environment Agency website, 2017).

Arpley Landfill

Arpley Landfill is regulated by the Environment Agency (EA) under an Environmental Permit. Data held by WBC for the Arpley Landfill site included a copy of the Environmental Statement for each of the recent planning applications (2011) for the proposed landfill extension, a copy of the EA Environmental Permit and a 2011 site record summary from the WBC Database of Potentially Contaminative Land use.

Site investigation data for Arpley Landfill, in particularly intrusive ground investigation reports and exploratory hole logs, was limited however numerous reports and assessments have been undertaken by Golder Associates in relation to the engineering design and stability of the landfill.

Warrington Borough Council Database of Potentially Contaminative Land use:

Site ID: 220

Site Name: Arpley Landfill Site

Site History: 1896 – Undeveloped

1967 – Walton Dredging Deposit Ground (centre), Arpley Dredging Deposit Ground (east). Details of the dredging deposits are included within Cheshire Waste Disposal Authority, site investigation report for the proposed Walton/Arpley Landfill Development, dated January 1986. The report states that the dredging deposit grounds began to the northeast of the site and extended into phases to cover most of the northeast and central area of the site. The dredging's were mainly derived from navigable stretches of the River Mersey and were contained within earth and silt embankments. The deposit grounds are described as generally between 4 – 6m above the original ground level.

1993 – Labelled as Arpley Landfill Site

2006 – Arpley Landfill Site. Tanks in the NE of the site

Current Land Use: Operational site with waste management number 53557, Environmental Permit EAEPR\EA/EPR/EP3292CM/V002, operated by 3C Waste Limited, a subsidiary of FCC Environment. The facility operates under a series of planning consents dating back to 1986. The original consent (1/17988), time limited waste disposal to 25 years. The landfill is partially restored (as of 2011) and includes mixed woodland, scrub, and grassland. Approx. 100ha of restored area.

Arpley Landfill Phases

Arpley Landfill site is divided into 5 phases; Lapwing Phase, Walton Phase, Birchwood Phase, Boundary Phase and Arpley Phase, the approximate location of which is shown on Figure 2. These phases are further sub-divided into a series of non-uniform cells, each with its own individual side and basal membrane liner, leachate drainage/collection system, landfill gas collection system and surface capping layer.

Cell Construction

Details regarding the cell lining system and capping layers within Arpley Landfill are included within the Golder Associates Arpley Gas Risk Assessment, Report No. 09514290329/A.0, dated February 2010.

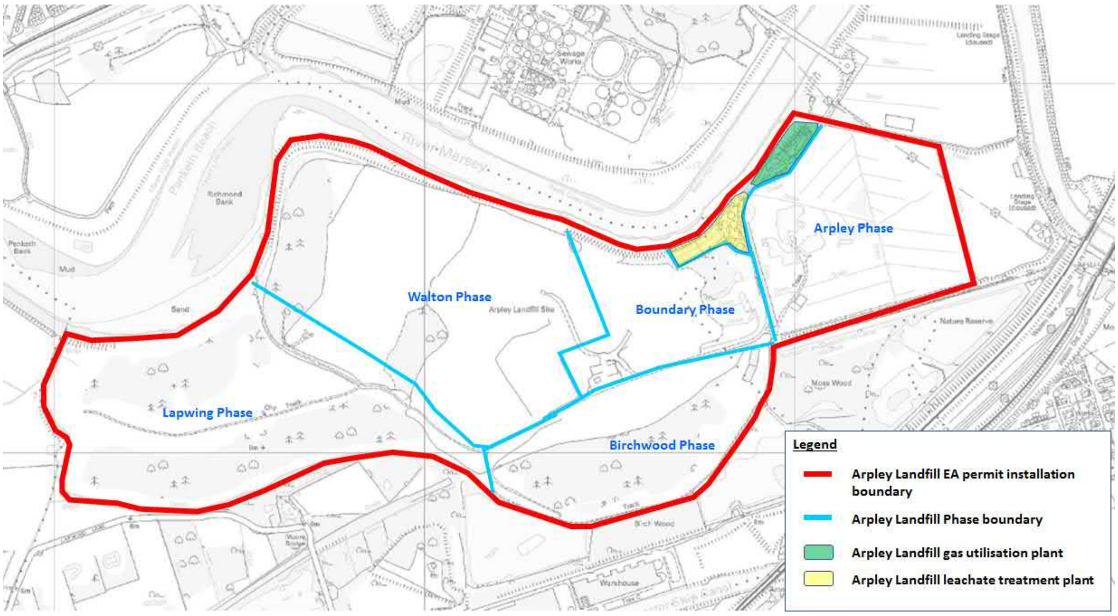


Figure 2 Arpley Landfill Phase boundaries (source: Golder Associates, 2010) and EA permit installation boundary (EA permit no. ref EPR/BS7668IH).

The Golder Associates report describes temporary and permanent capping will be applied in a progressive manner across the site. The permanent cap and gas collection systems have been (and are to be installed), the year following final waste placement. The permanent cap on all cells will likely comprise a single membrane liner consisting of 0.5mm HDPE (Birchwood, Lapwing and parts of Walton Phase) or 1mm LLDPE geomembrane (part of Walton, Boundary and Arpley Phases).

The lining of the cells (excluding Birchwood Phase) for the landfill gas risk assessment were modelled as being lined with a composite lining system of either 2mm HDPE geomembrane and 200mm of bentonite enhanced soil (BES); 300mm of BES; at least 1m of in-situ clay or 1m of engineered clay, respectively. Details of the landfill gas collection system were not available.

Golder Associates 2010, Arpley Landfill Capping Stability Assessment describes the site containment engineered capping layer to comprise; 1.2 -1.8m thick restoration soils (dredging deposits), underlain by a low permeability 1mm LLDPE membrane and a 0.3m regulating layer. Golder Associates 2011, Arpley stability technical memo, identifies the maximum depth of waste at Arpley Landfill site is assumed to be 30m (plus soil cap).

The side slope liners (gradient 1:2.5) are identified to comprise capping soil, filter geotextile, 300mm thick 10/20 Gc 80/20 drainage aggregate, protector geotextile, 2mm thick HDPE double textured geomembrane, a minimum 500mm thick engineered clay with a maximum permeability of 1 x 10^{-10} m/s, overlying the prepared formation comprising the engineered fill (waste material).

The leachate management system varies between the individual cells, but typically comprises a drainage blanket, main pipework system of HDPE pipes (160mm to 250mm diameter) and branch pipes (120mm to 160mm diameter) and a leachate collection point. The leachate is subsequently transferred to the on-site leachate treatment plant (the location is shown on Figure 2).

The northern boundary of Arpley Landfill, comprises the 'Mersey Bund' which has been engineered as part of the landfill (and includes shear strength parameters) and forms the 'toe' of the northern landfill slope. The Golder Associates 2004 stability risk assessment for Arpley Landfill identifies that the northern side slope design must achieve a minimum factor of safety of 1.3.

The Western Link Stage 2 route option D is currently identified as transecting 3 Phases of Arpley landfill (Arpley, Boundary and Walton Phases), which includes at least 9 separate cells (as of 2010), the main site access road, the leachate treatment plant and Mersey Bund.

Environmental Permit

The Arpley Landfill site is currently permitted, a copy of Permit Number EPR/BS7668IH details requirements for the site, which include requirements for leachate collection and treatment, to collect landfill gas, to control the migration of landfill gas and to collect the gas to produce energy. If unsuitable the gas is to be flared. There is a requirement to carry out a topographic survey annually and following closure of the landfill.

The environmental permit for the site lists the following permitted wastes; Lubricants (oils and greases), antifreeze, Mining/Quarrying wastes, Agricultural wastes, waste from food/wood/leather/oil refining processes, coatings manufacture, thermal processes, construction and demolition waste including asbestos (ACM), and asbestos cement.

Gatewarth Landfill

A vast amount of files/data is held by WBC for Gatewarth Landfill site (also named as Gatewarth Farm Landfill), including intrusive site investigation reports, records of pollution incidents and a 2008 site record summary from the WBC Database of Potentially Contaminative Land use. The relevant data for the landfill site, in relation to the proposed Western Link route options (Option D and Option F), is summarised below.

Warrington Borough Council Database of Potentially Contaminative Land use:

Site ID: 198

Site Name: Gatewarth Landfill Site

Site History: 1896 – Open fields with marsh areas

1967 – Eastern area of the site marked as a refuse tip

1989 – Western area of the site marked as a refuse tip

1993 – Building on eastern part of the site, labelled as 'household waste site'

2007 – Refuse tip no longer marked

Overview: Gatewarth Farm landfill (130acres) is a pre-licenced landfill site, subdivided into 3 phases, as shown on Figure 3 and described in further detail below. Planning permission for the tipping of waste at Gatewarth Landfill was granted in 1968, with tipping commencing in 1970. Gatewarth Landfill was used for the disposal of industrial and domestic waste and the site was licensed for the disposal of radioactive material but specific details are not given on this.

Leachate outbreaks have been identified in Phases 2 & 3, along the perimeter of the landfill, via overspill from the containment bunds, through underlying soils, overland flow and migration into groundwater. The leachate outbreaks have resulted in closure of the public footpaths on several occasions. The leachate was found to contain elevated concentrations of arsenic, lead and PAHs. From 1997 elevated levels of ammonia, chloride, cadmium, sodium and phenol have been recorded.

The council conducted ground gas monitoring in 1999-2000, where methane concentrations of 60% and carbon dioxide concentrations of 20-30% were recorded.

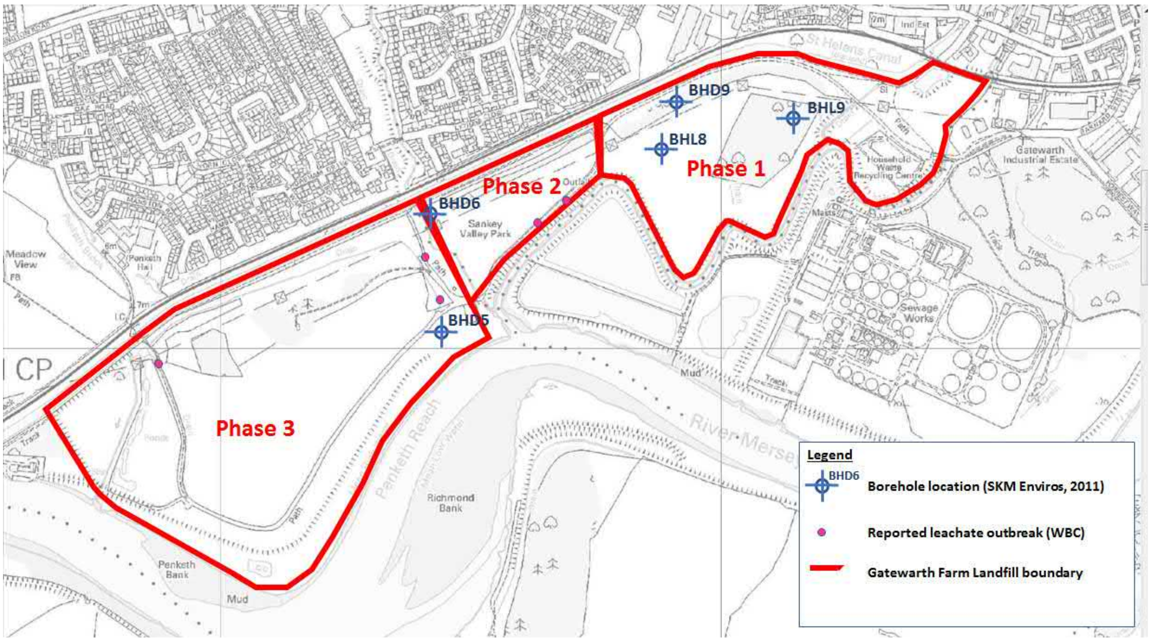


Figure 3: Gatewarth Landfill Phase location boundaries, WBC recorded leachate outbreak locations and approx. position of relevant borehole locations.

A report produced by Allott and Lomax Consulting Enginners, May 1999 describes the waste at Gatewarth Landfill as very heterogeneous in nature. The report, which investigated the remedial options for the management of leachate discharges, also suggested that removing the leachate from the site could cause waste settlement, which could prove catastrophic in the areas around the pylons.

Gatewarth Landfill Construction

Gatewarth Landfill site does not have an engineered side/basal liner, with the fill material being directly underlain by alluvial deposits. The interface between the top of the alluvial deposits and the bottom of the waste material is 5-6.5m AOD. The site is recorded as being capped with topsoil and an underlying clay cap between 0.2m to 1.4m thickness (Allott and Lomax, 1999).

Bunds have been created on site for flood protection. Settlement of the waste has created depressions across the site, which have gradually developed into ponds. In 2004 a section of the Sankey Brook embankment in Phase 1 collapsed and works were conducted to repair the bank. Bank stability was checked by the council every 6months (as of 2008). Inspections for leachate were undertaken regularly by the Council Ranger service, however as a result of council cut-backs this is no longer undertaken and the council now operates a reactive response following complaints from the public.

Historic borehole records have been viewed from a site investigation undertaken by SKM Enviros titled Former Gatewarth Landfill, Warrington Part 2A Compliant B20C inspection Final v1, dated August 2011, project number JL30271.

The following exploratory holes from this investigation are considered relevant to the current proposed route options (options D and F): BHD5, BHS5, BHS6, BHD6, BHS9, BHD9, BHL9 and BHL8. The borehole logs are included as Appendix A and the approximate locations of the exploratory holes are shown on Figure 3.

During the site investigation works all soil and waste arisings were screened using a 44B Geiger Counter, measuring ionising radiation. The readings were typical of background levels (5-10 cps within BHL8).

<u>Gatewarth Landfill Phase 1 & 2</u>:

Phase 1 and Phase 2 are recorded as being infilled between 1971 – 1977 with 457,000m^3 waste including domestic, civic amenity, highways, excavation/rubble, industrial and difficult liquid sludge and solids. The deposited waste split is documented to be approximately 40% domestic waste and 60% industrial waste. The following industrial wastes are documented as having been input (SKM Enviros, 2011):

Soap waste, ferrous waste, oils, asbestos, potentially combustible waste, paint sludge, sodium hydroxide, filter sludge, animal processing wastes, industrial effluent, demolition rubbles with potential radiological contamination, alkali metal oxides, calcium hydroxide, farm wastes, fats, waxes, greases, food processing waste, glue waste, iron compounds, interceptor pit wastes, latex/rubber solutions, mineral processing waste, oil/water mixes organic acids, printing industry wastes, tannery and fellmongers waste, tar, pitch, bitumen and asphalt and titanium compounds.

The SKM Enviros report, 2011 details a report obtained from the EA and produced by Manchester University Pollution Research Unit which refers to potential radioactive material being deposited within Gatewarth Landfill. The report states that a maximum of 400 tonnes per day of radioactive waste from the demolition of buildings formerly occupied by Thorium Chemicals Ltd of Widnes is likely to have been deposited at the site between May 1976 and January 1977.

This point is supported via email correspondence between Will Watson at Halton Borough Council and Karen Young at Warrington Borough Council, dated 18/03/2005, which states that ‘Thorium Limited site was subject to de-contamination in the 1970s and the file notes from the time (1976) say that some ‘slightly’ radioactively contaminated rubble was sent to Gatewarth tip to be buried under 6ft of top cover’.

Furthermore, anecdotal evidence from WBC minutes suggests that radioactive material from one of the early nuclear reactors built by the UK Atomic Energy Authority at Risley, were dumped at Gatewarth when the installations were dismantled.

The Allott and Lomax 1999 report describes the following general stratigraphic sequence for Phase 1:

140mm average topsoil depth, underlain by 0.4m to 1.4m capping material comprising sandy silty clay and up to 10.2m depth of waste (BH4).

The SKM Enviros, 2011 site investigation details the stratigraphy within Phase 1 adjacent to the proposed alignment of Route Option F, as Made Ground comprising firm brown sandy gravelly clay between 0.5m to 1.5m, underlain by landfill waste to 8.0m bgl. The landfill waste comprises cardboard, rags, glass, timber, plastic, concrete, metal cans, rubber, ash, coal, slag and polystyrene. A sheen was noted on the soil matrix.

The Made Ground material is underlain by brown coarse sand (BHL9) within the east side of Phase 1 and stiff brown slightly gravelly clay (BHL8) within the west of Phase 1, both of which were proven to 9.0m bgl. Borehole BHD9, located within the northwest of Phase 1 and adjacent to St Helens Canal, encountered Made Ground comprising soft to firm brown gravelly clay to 2.7m bgl, and is underlain by sand deposits to 6.0m bgl. This was subsequently underlain by stiff brown slightly gravelly clay to 20.50m bgl. Sandstone was encountered underlying the clay and proven to 30.0m bgl. No in-situ geotechnical testing was presented on the borehole logs.

Phase 2 was noted as generally 150mm topsoil, underlain by 0.2m – 0.5m capping, with waste (comprising dry friable soil with lots of degradable matter) to a maximum depth of 6.7m (Cheshire County Council Engineering Service ground investigation report). The SKM Enviros, 2011 site investigation details the stratigraphy within BHS6, located within the western corner of Phase 2 and adjacent to the proposed alignment of Route Option D, as alluvial deposits comprising sandy clay (with sand and silt bands 4.2-5.0m bgl), from ground level to 18.0m bgl. The clay is described as soft from ground level to 4.2m bgl, stiff from 5.0m to 7.5m bgl and very stiff between 7.5m bgl to 18.0m bgl. Brown sand was encountered at 18.0m bgl to 21.0m bgl, underlain by red sandstone, which was proven to 30.0m bgl.

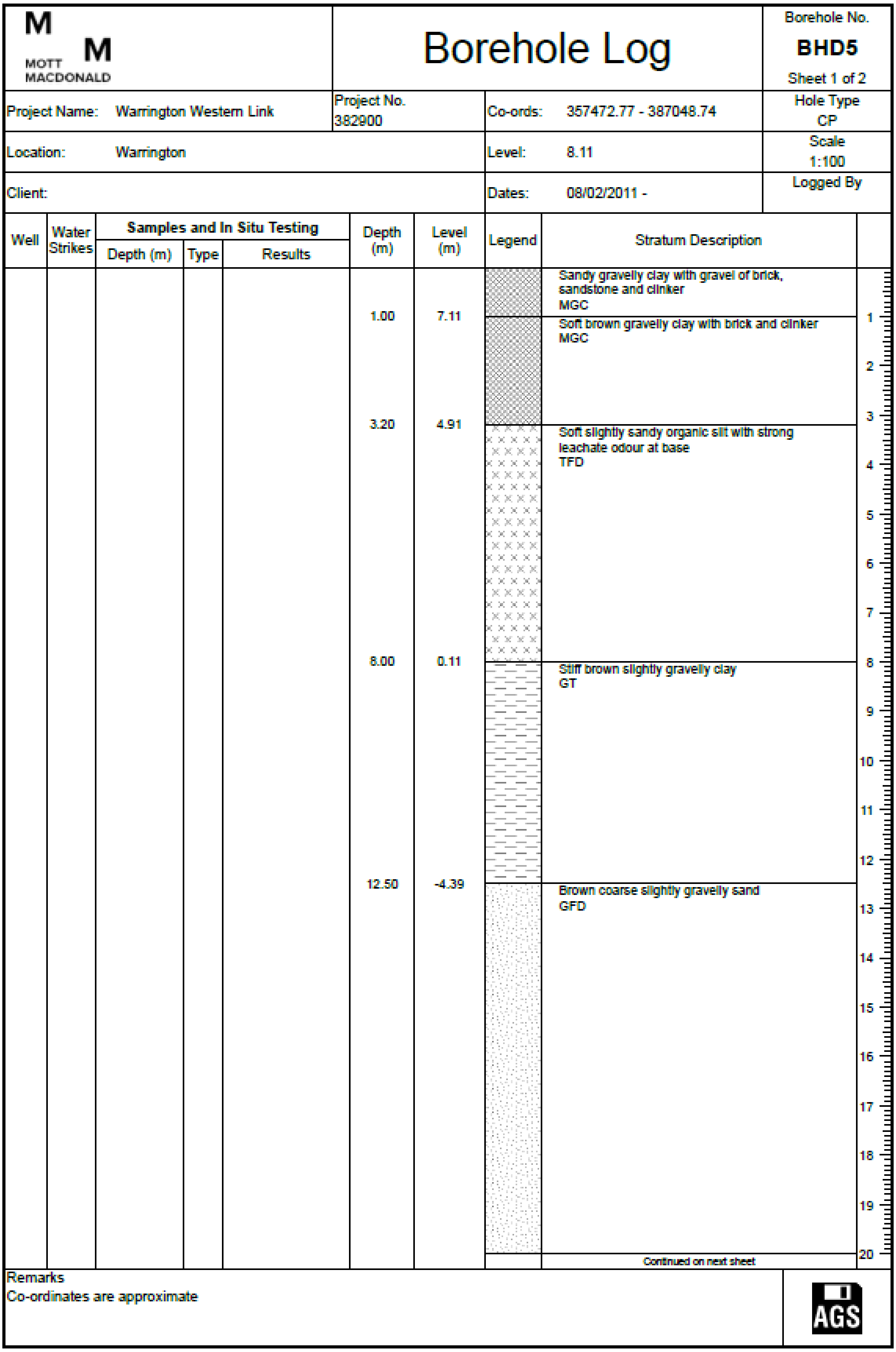
Gatewarth Landfill Phase 3:

Phase 3 is recorded as being infilled between 1977 – 1988, with 108,600m^3 of unknown waste. Historical reports identify waste fill material up to 17m thick. Reed beds have been planted in Phase 3 to enhance the removal of leachate (Allott and Lomax, 1999), which is also facilitated by a series of leachate collection drains around the perimeter and a wind pump and leachate collection chamber located adjacent to Sankey Brook.

The SKM Enviros, 2011 site investigation details the stratigraphy within BHD5 (Figure 3), located within Phase 3 and adjacent to the proposed alignment of Route Option D, as Made Ground up to 3.20m depth comprising sandy gravelly clay with brick, plastic, timber and cobbles of slag and sandstone. The Made Ground was underlain by Alluvial deposits to 8.0m bgl, comprising soft, slightly sandy organic silt. Groundwater strike (including a strong leachate odour) was noted at 6.20m bgl. Till was encountered as firm and stiff brown slightly gravelly clay, from 8.0m to 12.5m bgl.

A brown coarse slightly gravelly sand was encountered underlying the Till, to 21.0m bgl, possibly representing weathered Sandstone. Red Sandstone was encountered below the gravelly sand and proven to 30.0m bgl. No geotechnical in-situ testing was presented on the borehole log.

APPENDIX A – Gatewarth Landfill Borehole logs



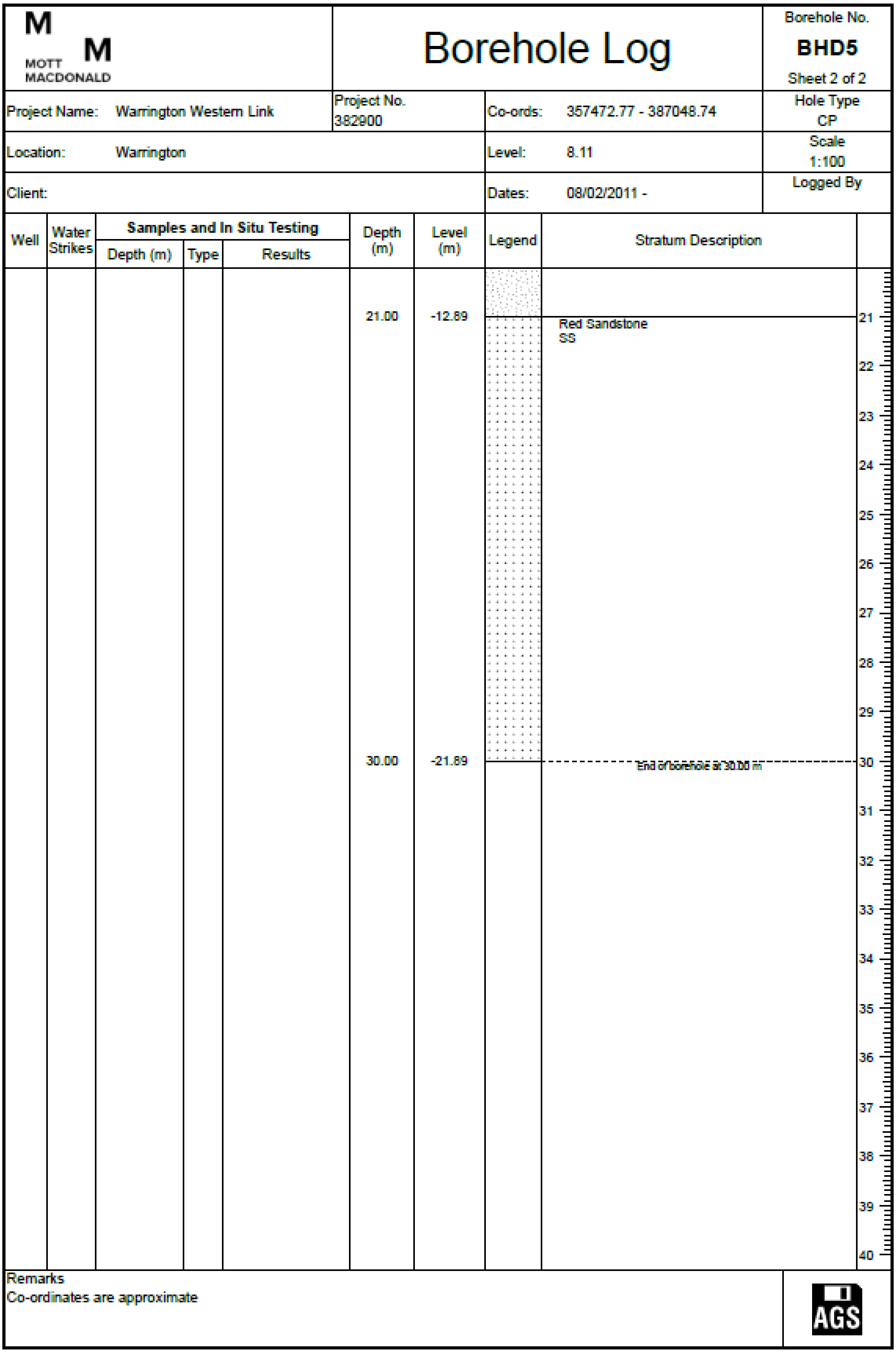
Borehole Log

Borehole No. BHD5	Sheet 1 of 2		
Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357472.77 - 387048.74	Hole Type CP
Location: Warrington		Level: 8.11	Scale 1:100
Client:		Dates: 08/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
							▒	Sandy gravelly clay with gravel of brick, sandstone and clinker MGC
					1.00	7.11	▒	Soft brown gravelly clay with brick and clinker MGC
					3.20	4.91	×	Soft slightly sandy organic silt with strong leachate odour at base TFD
					8.00	0.11	▤	Stiff brown slightly gravelly clay GT
					12.50	-4.39	░	Brown coarse slightly gravelly sand GFD

Continued on next sheet

Remarks
Co-ordinates are approximate

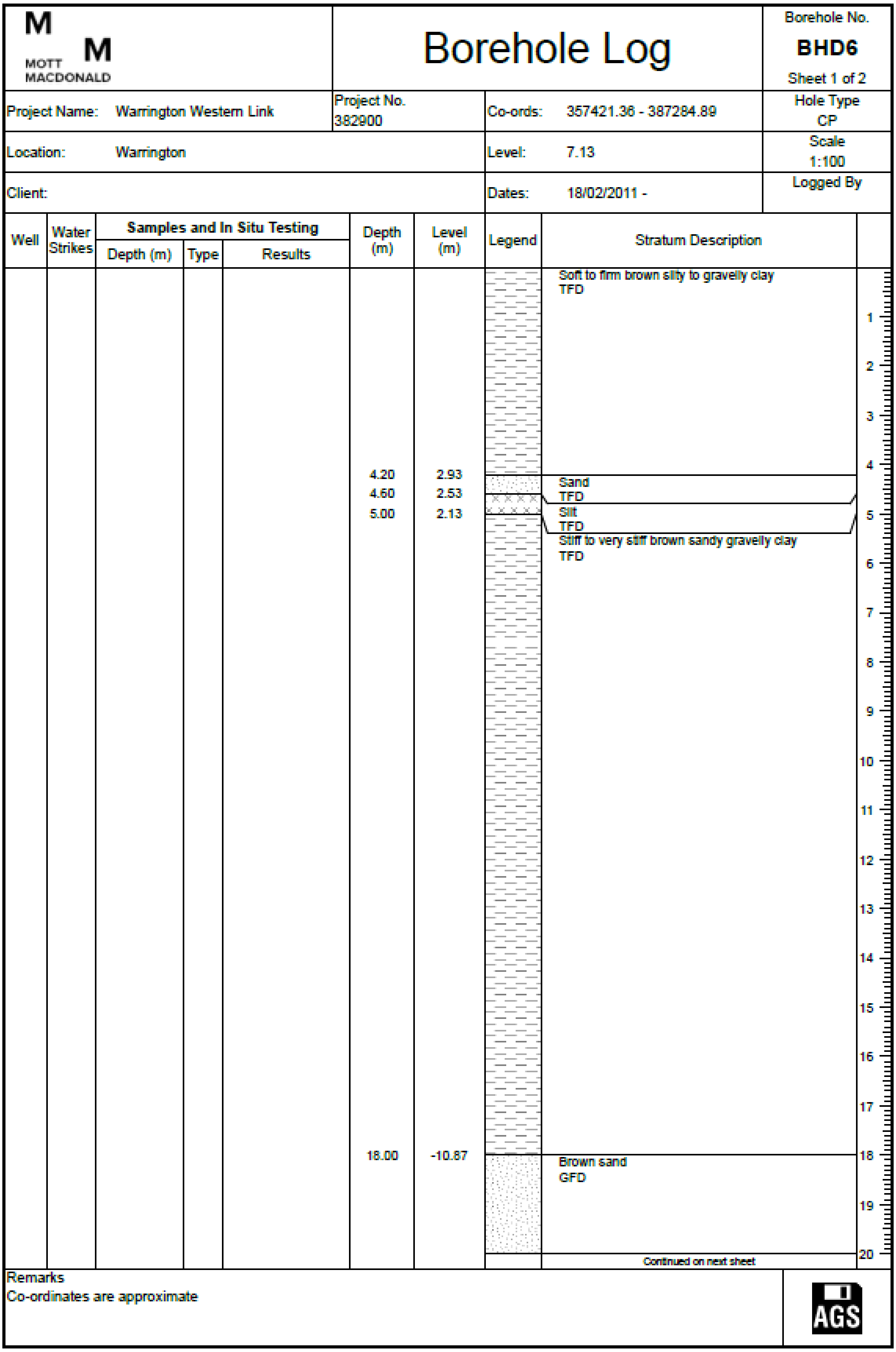


Borehole Log

Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357472.77 - 387048.74	Borehole No. **BHD5** Sheet 2 of 2
Location: Warrington		Level: 8.11	Hole Type CP
Client:		Dates: 08/02/2011 -	Scale 1:100
			Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					21.00	-12.89		Red Sandstone SS
					30.00	-21.89		End of borehole at 30.00 m

Remarks
Co-ordinates are approximate



Borehole Log

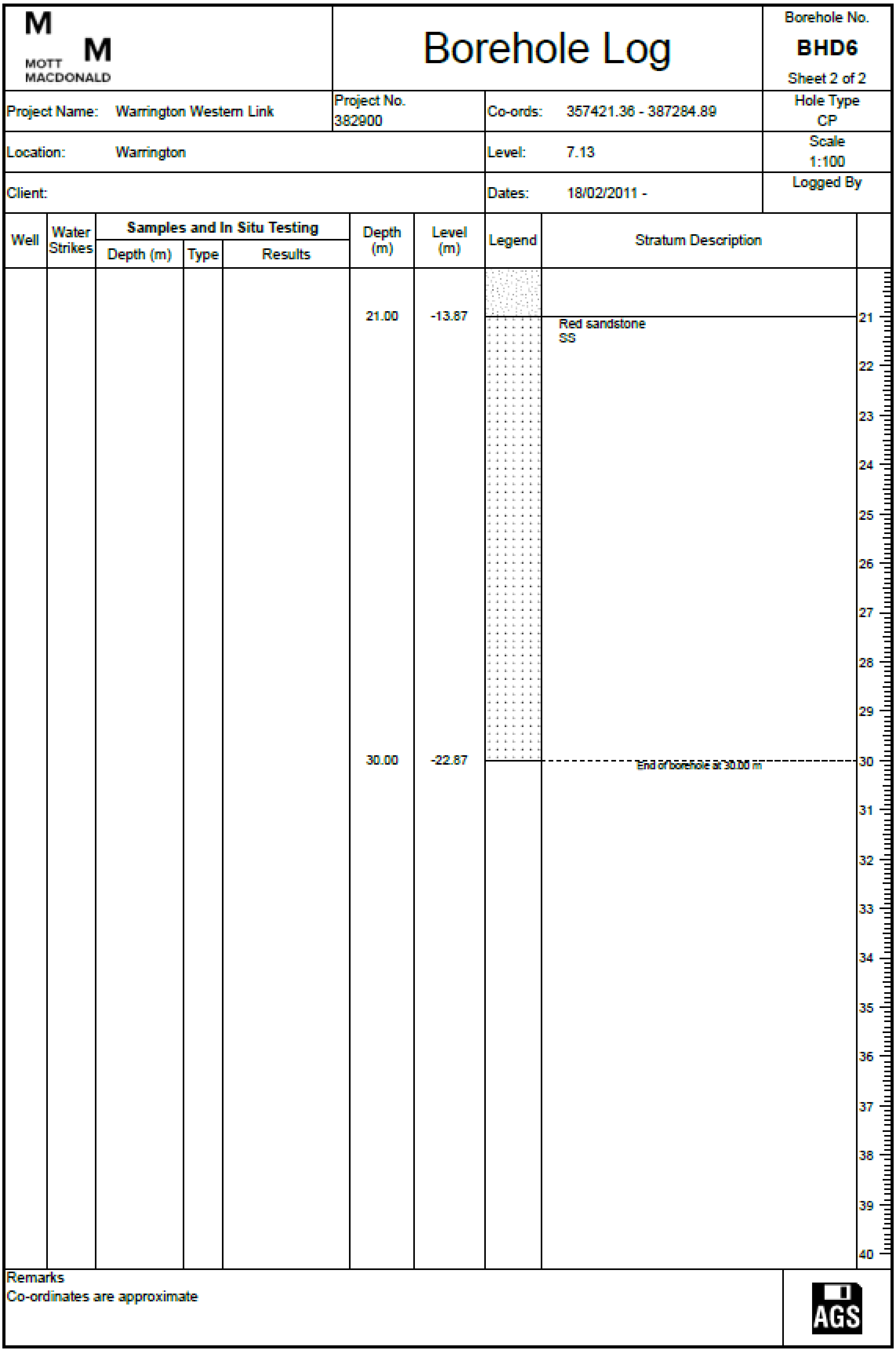
Borehole No.
BHD6
Sheet 1 of 2

Project Name:	Warrington Western Link	Project No. 382900	Co-ords:	357421.36 - 387284.89	Hole Type CP
Location:	Warrington		Level:	7.13	Scale 1:100
Client:			Dates:	18/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
								Soft to firm brown silty to gravelly clay TFD
					4.20	2.93		Sand TFD
					4.60	2.53		Silt TFD
					5.00	2.13		Stiff to very stiff brown sandy gravelly clay TFD
					18.00	-10.87		Brown sand GFD

Continued on next sheet

Remarks
Co-ordinates are approximate



Borehole Log

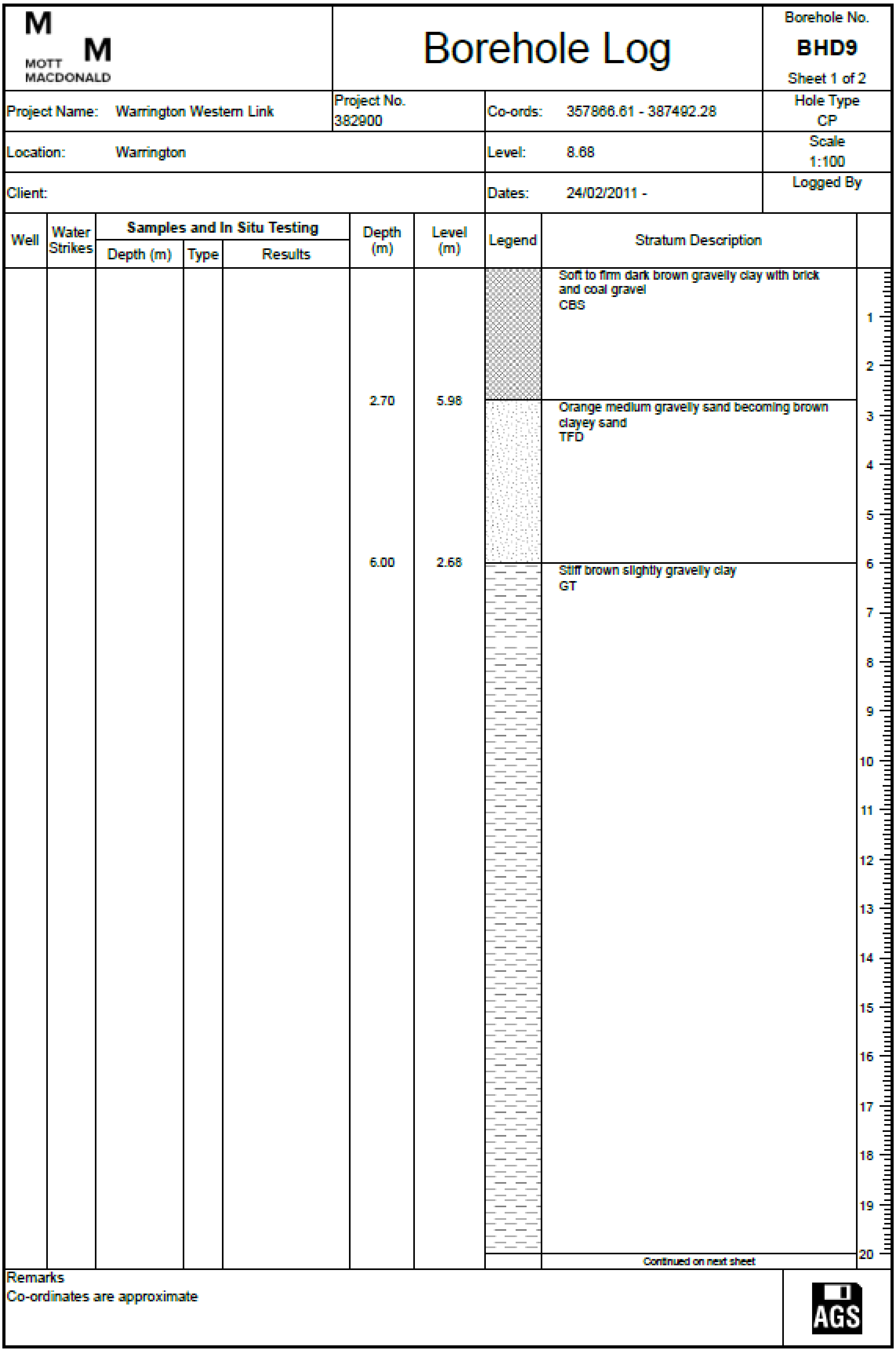
MOTT MACDONALD

Borehole No.
BHD6
Sheet 2 of 2

Project Name:	Warrington Western Link	Project No. 382900	Co-ords: 357421.36 - 387284.89	Hole Type CP
Location:	Warrington		Level: 7.13	Scale 1:100
Client:			Dates: 18/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					21.00	-13.87		Red sandstone SS
					30.00	-22.87		End of borehole at 30.00 m

Remarks
Co-ordinates are approximate



MOTT MACDONALD

Borehole Log

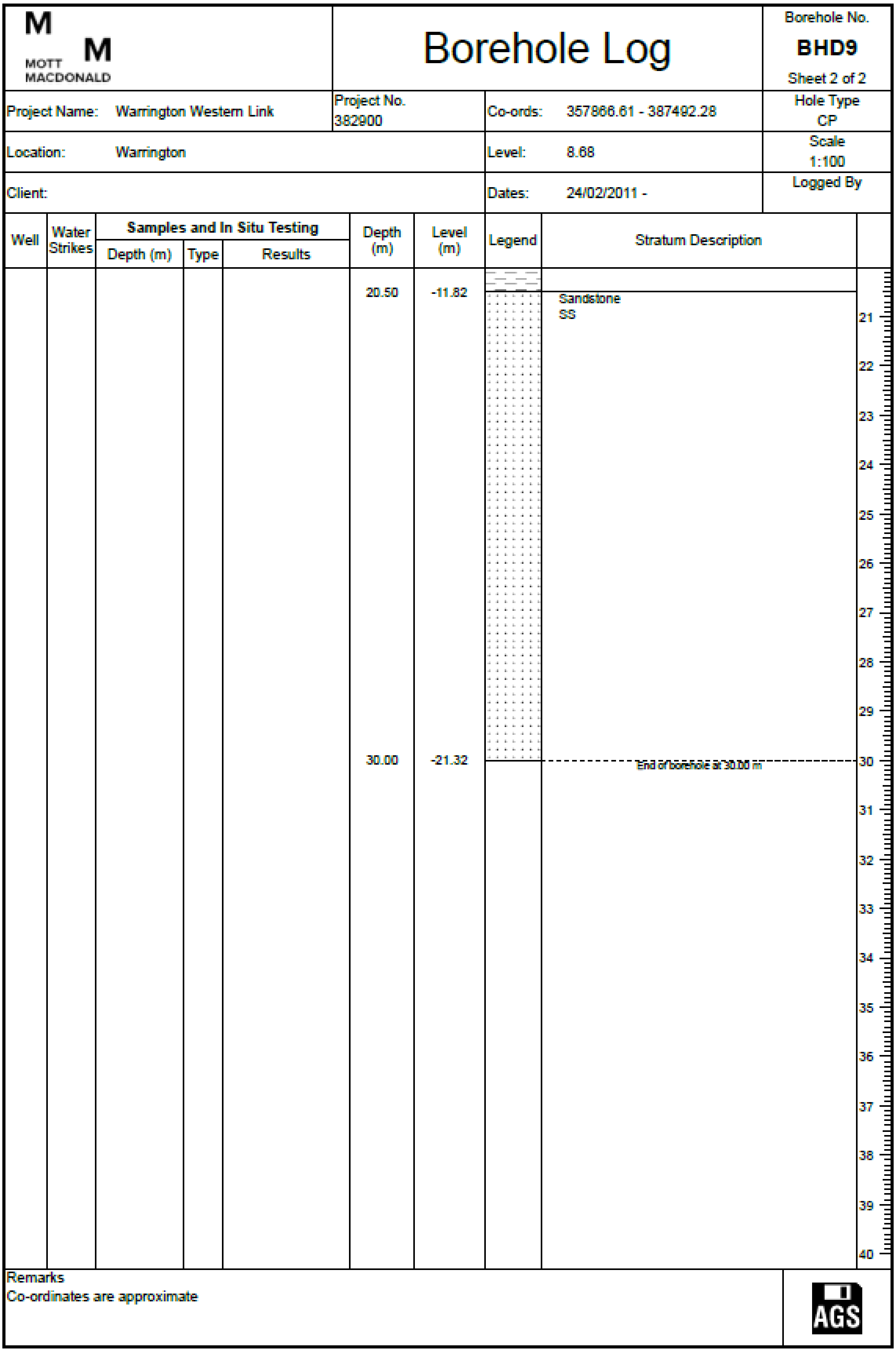
Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357866.61 - 387492.28	Borehole No. **BHD9** Sheet 1 of 2
Location: Warrington		Level: 8.68	Hole Type CP
Client:		Dates: 24/02/2011 -	Scale 1:100
			Logged By

Well	Water Strikes	Samples and In Situ Testing: Depth (m)	Type	Results	Depth (m)	Level (m)	Legend	Stratum Description
					2.70	5.98		Soft to firm dark brown gravelly clay with brick and coal gravel CBS
					6.00	2.68		Orange medium gravelly sand becoming brown clayey sand TFD
								Stiff brown slightly gravelly clay GT

Continued on next sheet

Remarks
Co-ordinates are approximate

AGS



Borehole Log

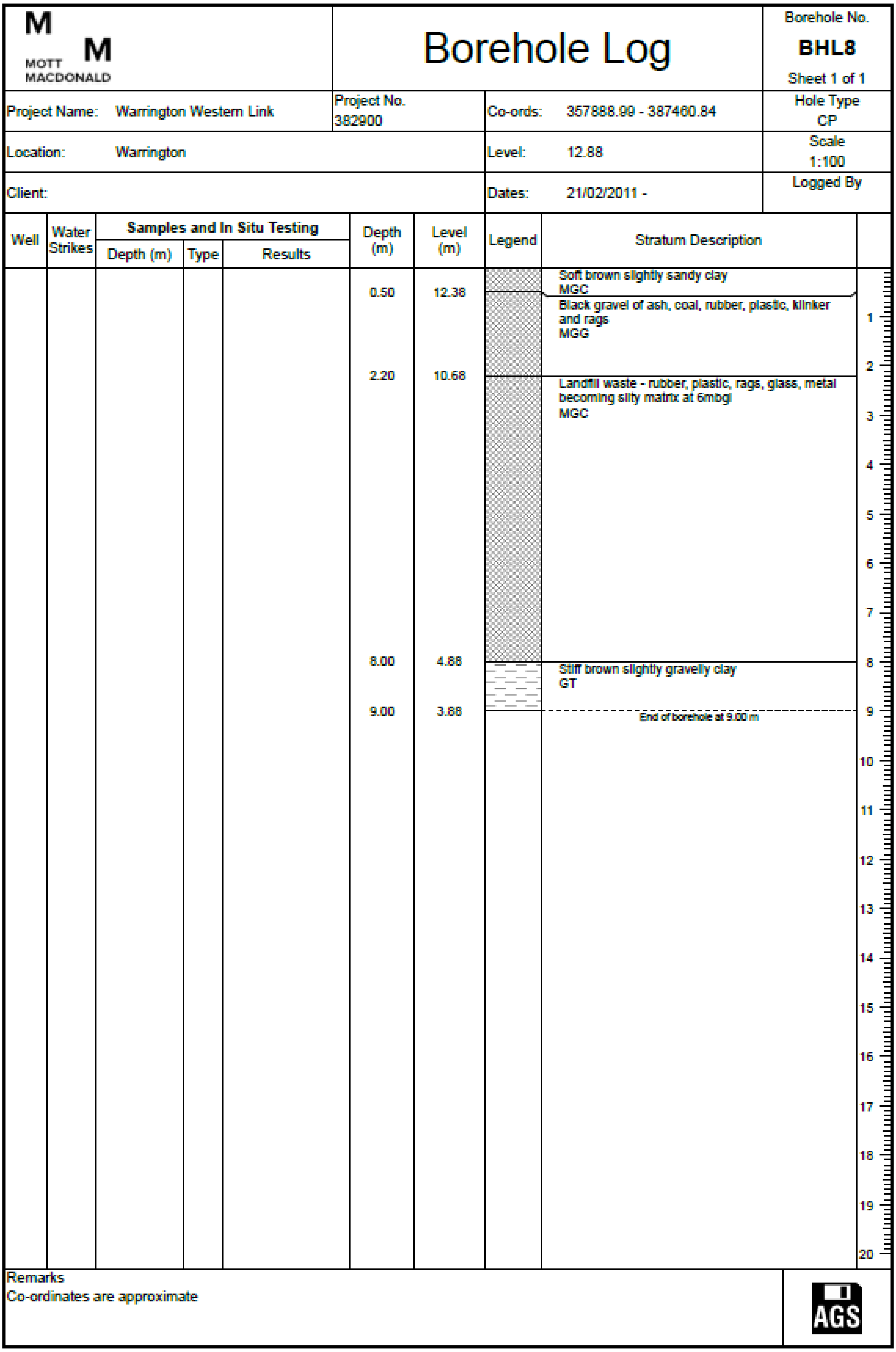
Borehole No. **BHD9**

Sheet 2 of 2

Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357866.61 - 387492.28	Hole Type CP
Location: Warrington		Level: 8.68	Scale 1:100
Client:		Dates: 24/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					20.50	-11.82		Sandstone SS
					30.00	-21.32		End of borehole at 30.00 m

Remarks
Co-ordinates are approximate

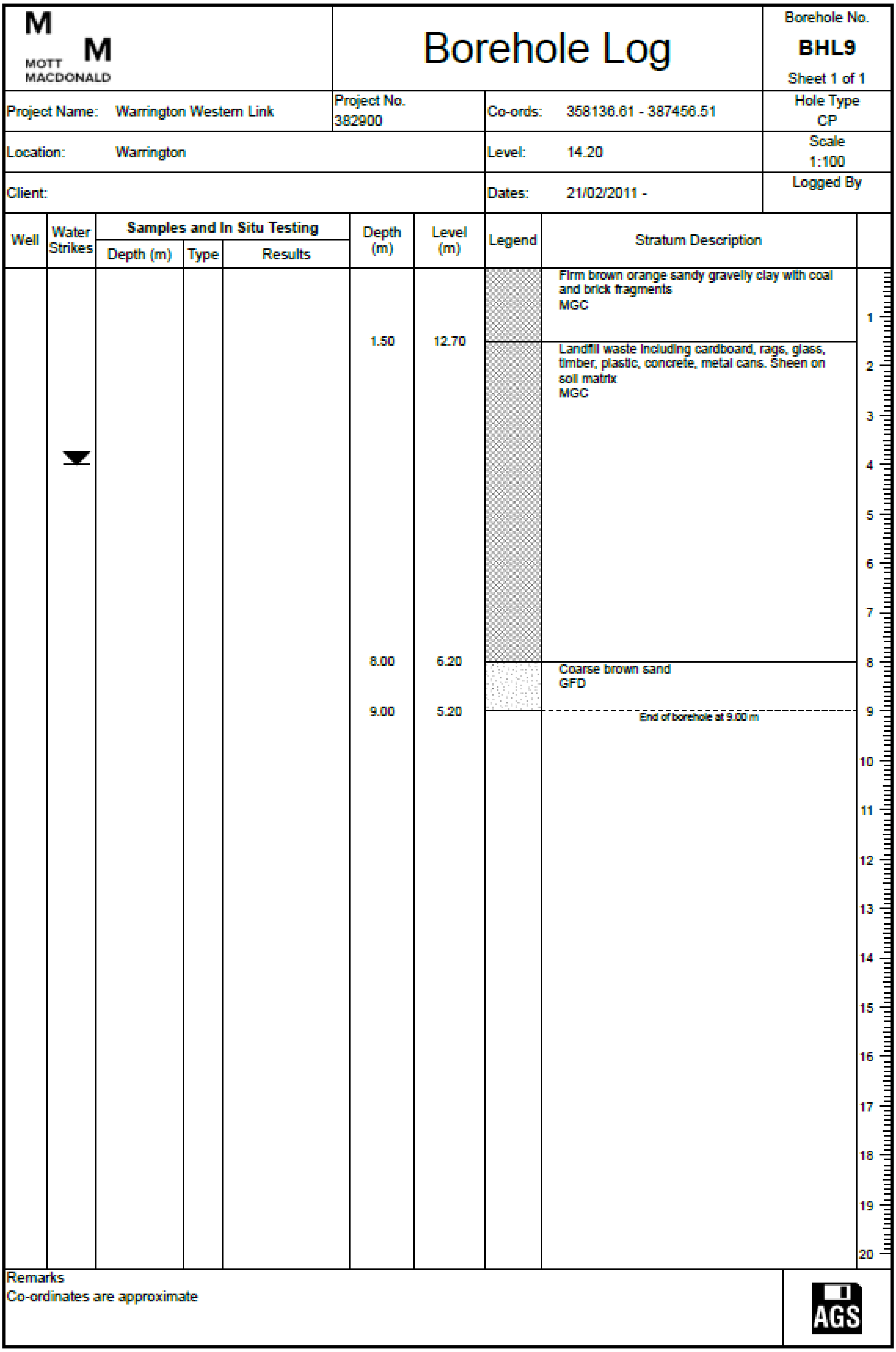


Borehole Log

Borehole No.	BHL8	Sheet 1 of 1	
Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357888.99 - 387460.84	Hole Type CP
Location: Warrington		Level: 12.88	Scale 1:100
Client:		Dates: 21/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.50	12.38	▨	Soft brown slightly sandy clay MGC
					2.20	10.68	▨	Black gravel of ash, coal, rubber, plastic, klinker and rags MGG
					8.00	4.88	▨	Landfill waste - rubber, plastic, rags, glass, metal becoming silty matrix at 6mbgl MGC
					9.00	3.88	▤	Stiff brown slightly gravelly clay GT
								End of borehole at 9.00 m

Remarks
Co-ordinates are approximate

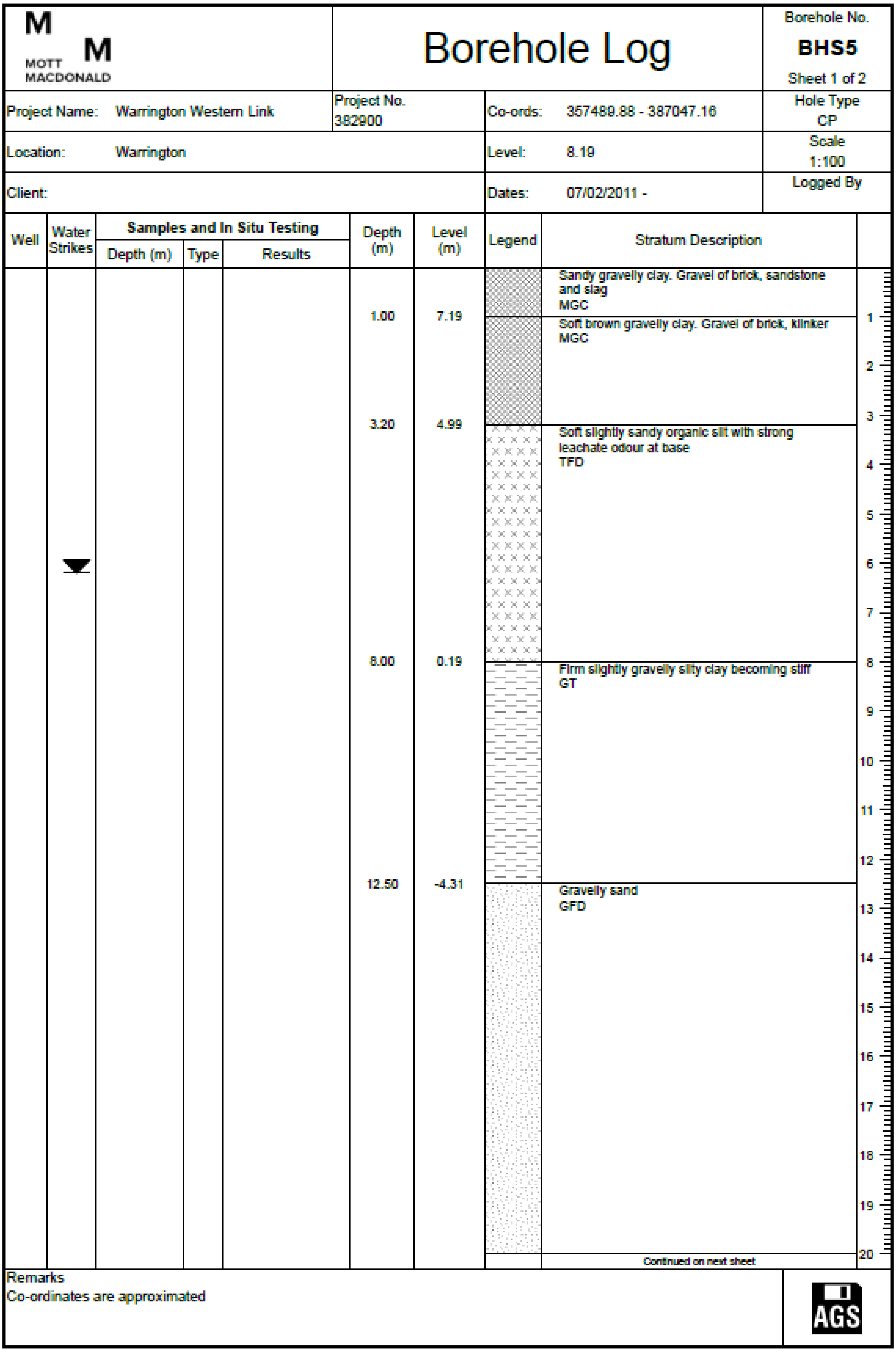


Borehole Log

Borehole No.	**BHL9**
Sheet 1 of 1	
Project Name:	Warrington Western Link
Project No.	382900
Co-ords:	358136.61 - 387456.51
Hole Type	CP
Location:	Warrington
Level:	14.20
Scale	1:100
Client:	
Dates:	21/02/2011 -
Logged By	

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					1.50	12.70	▒	Firm brown orange sandy gravelly clay with coal and brick fragments MGC
	▼				8.00	6.20	▒	Landfill waste including cardboard, rags, glass, timber, plastic, concrete, metal cans. Sheen on soil matrix MGC
					9.00	5.20	░	Coarse brown sand GFD
								End of borehole at 9.00 m

Remarks
Co-ordinates are approximate



Borehole Log

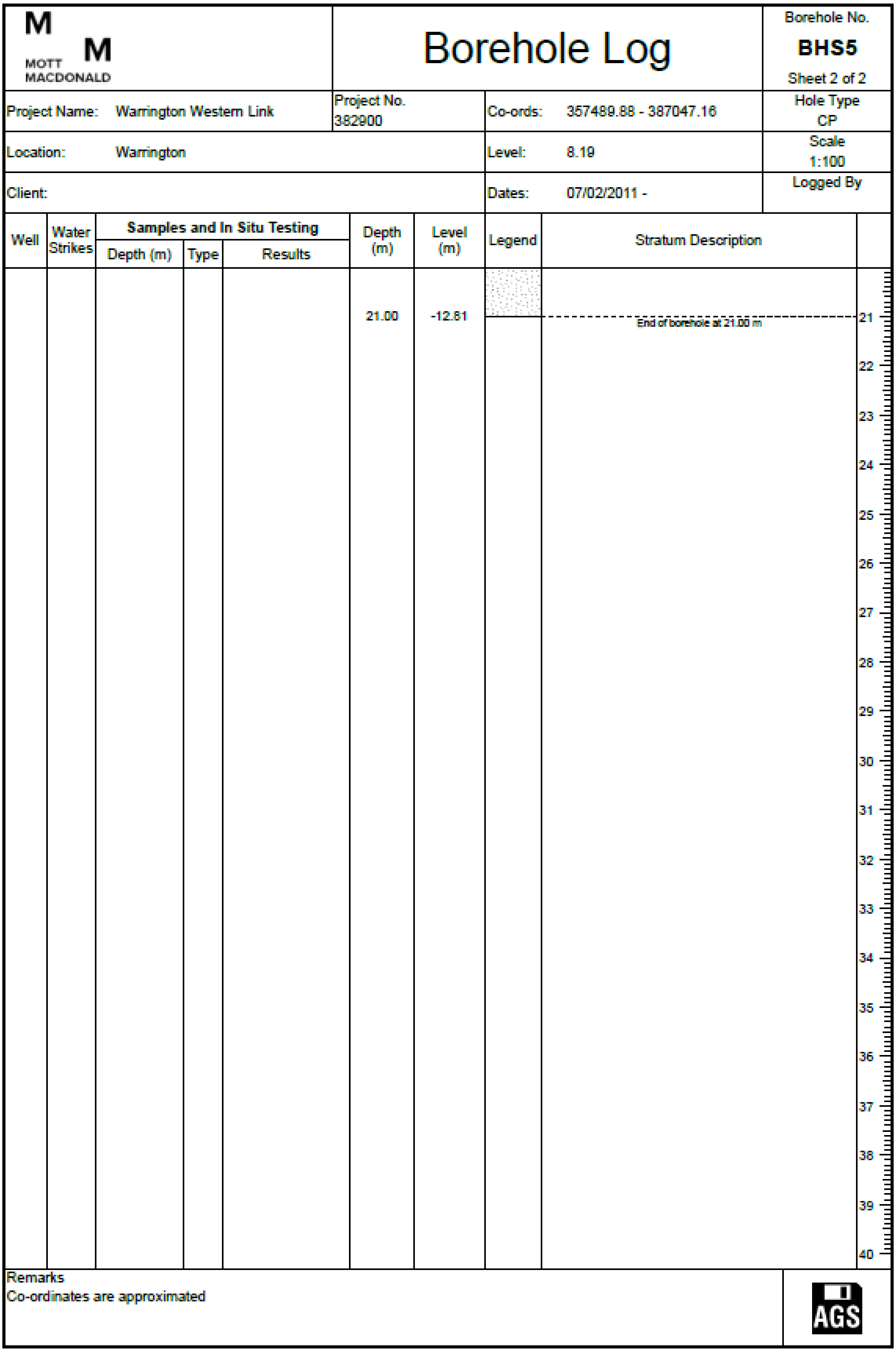
Borehole No.
BHS5
Sheet 1 of 2

Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357489.88 - 387047.16	Hole Type CP
Location: Warrington		Level: 8.19	Scale 1:100
Client:		Dates: 07/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
								Sandy gravelly clay. Gravel of brick, sandstone and slag MGC
					1.00	7.19		Soft brown gravelly clay. Gravel of brick, klinker MGC
					3.20	4.99		Soft slightly sandy organic silt with strong leachate odour at base TFD
	▼							
					8.00	0.19		Firm slightly gravelly silty clay becoming stiff GT
					12.50	-4.31		Gravelly sand GFD

Continued on next sheet

Remarks
Co-ordinates are approximated



Borehole Log

Project Name: Warrington Western Link	Project No. 382900	Co-ords:	357489.88 - 387047.16	Borehole No. **BHS5** Sheet 2 of 2
Location: Warrington		Level:	8.19	Hole Type CP
				Scale 1:100
Client:		Dates:	07/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					21.00	-12.81	▨	End of borehole at 21.00 m	21
									22
									23
									24
									25
									26
									27
									28
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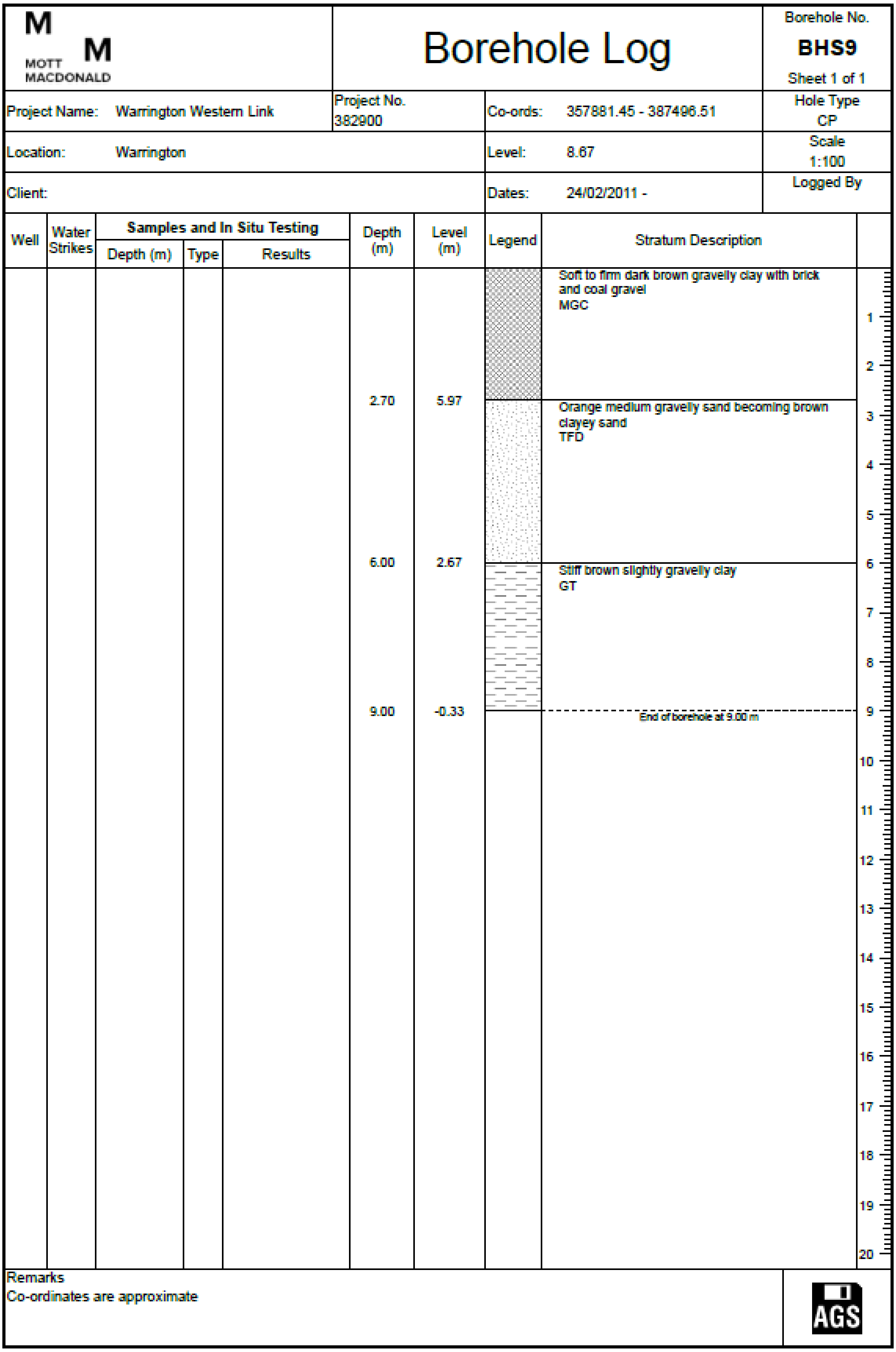
Remarks
Co-ordinates are approximated



Borehole Log

Project Name: Warrington Western Link	Project No. 382900	Co-ords: 357881.45 - 387496.51	Borehole No. **BHS9** Sheet 1 of 1
			Hole Type CP
Location: Warrington		Level: 8.67	Scale 1:100
Client:		Dates: 24/02/2011 -	Logged By

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					2.70	5.97	▨	Soft to firm dark brown gravelly clay with brick and coal gravel MGC
					6.00	2.67	░	Orange medium gravelly sand becoming brown clayey sand TFD
					9.00	-0.33	▤	Stiff brown slightly gravelly clay GT
								End of borehole at 9.00 m

Remarks
Co-ordinates are approximate

D. Arpley Meadows GI

IAN FARMER ASSOCIATES

WARRINGTON BOROUGH COUNCIL

ARPLEY MEADOWS
WARRINGTON

GROUND INVESTIGATION REPORT

Contract: 41932

Date: December 2016

Ian Farmer Associates (1998) Limited
Unit 14-15, Rufford Court
Hardwick Grange, Warrington, WS1 4RF
Tel: 01925 855440
Email: warrington@ianfarmer.co.uk

REPORT ON GROUND INVESTIGATION

carried out at

ARPLEY MEADOWS,
WARRINGTON

Prepared for

WARRINGTON BOROUGH COUNCIL
Property and Estate Management,
Economic Regeneration, Growth & Environment,
Quattro,
Buttermarket Street,
Warrington.
WA1 2NL

Contract No: 41932

Date: December 2016

Ian Farmer Associates (1998) Limited
Unit 14-15, Rufford Court,
Hardwick Grange, Warrington WA1 4RF
Tel: 01925 855440
Email: warrington@ianfarmer.co.uk

Report Issue Log

Draft Issue	**Issued By** **ACO**	**Checked By** **TJD**
Issue Method **E~~/P/D~~**	Date **07/12/16**	Date **07/12/16**

Final Issue	**Issued By**	**Checked By**
Issue Method **E/P/D**	Date	Date

Revision	**Issued By**	**Checked By**
Issue Method **E/P/D**	Date	Date

Issue Method: E = Electronic
P = Paper
D = Disc

EXECUTIVE SUMMARY

On the instructions of Warrington Borough Council, an investigation was undertaken to determine ground conditions and enable a contamination risk assessment and a review of gas emissions to be undertaken. A Geotechnical and Geoenvironmental Desk Study Report was provided for use to IFA by the Client. The ‘Site’ referred to by IFA within this report forms part of a larger site which is being considered in terms of the potential for future residential development.

The site is situated approximately 1.5km south west of Warrington town centre and may be located by Grid Reference SJ592872. At the time of the investigation the site comprised the north western edge of a larger agricultural field, extending off to the south east. The River Mersey lay to the north west, beyond a vegetated buffer, with unallocated land to the north east. Beyond the south western extent lay a roundabout and associated land on Forrest Way.

The site work was carried out between the 17th and 25th October 2016, during which ten boreholes were undertaken by window sampler technique and forty-three trial pits were dug by mechanical excavator, set out on an approximate 25m grid in order to provide coverage across the site area.

Representative disturbed samples were taken from all pits and boreholes, with monitoring wells installed in all boreholes, which were subsequently monitored at regular intervals.

The sequence of the strata encountered during the investigation generally confirms the anticipated geology as interpreted from the geological map, with superficial Tidal Flat Deposits, comprising silty, clay and sand with peat, encountered in all locations. Depth to bedrock, the Wilmslow Sandstone Formation, was not proven,

Elevated arsenic and lead concentrations are deemed to be widespread across the site with respect to human health screening levels for a residential end-use. Whilst slight PAH exceedances have been observed, these are not deemed to be sufficiently elevated to represent any significant risk to human health.

Heavy metals, PAH and total TPH concentrations are observed to be elevated within the underlying groundwater, although there is no evidence for a potential on site source and it is considered that the results are representative of the underlying groundwater in the region, given the nearby major industry and landfill.

Further monitoring of ground gases may provide sufficient evidence to rule out the requirement for protection measures within any future properties, should development occur on the site.

CONTENTS

1.0 INTRODUCTION

1.1 On the instructions of Warrington Borough Council, an investigation was undertaken to determine ground conditions and enable a contamination risk assessment and a review of gas emissions to be undertaken.

1.2 A Geotechnical and Geoenvironmental Desk Study Report, dated 22/01/16 by Aecom, was provided for use to IFA by the Client. The ‘Site’ referred to by IFA within this report forms part of a larger site, as detailed within the above referenced desk study, which is being considered in terms of the potential for future residential development.

1.3 This report has been prepared for the sole use of the Client for the purpose described and no extended duty of care to any third party is implied or offered. Third parties using any information contained within this report do so at their own risk.

1.4 The comments given in this report and the opinions expressed herein are based on the information received, the conditions encountered during site works, and on the results of tests made in the field and laboratory. However, there may be conditions prevailing at the site which have not been disclosed by the investigation and which have not been taken into account in the report.

1.5 The comments on groundwater conditions are based on observations made at the time the site work was carried out. It should be noted that groundwater levels vary owing to seasonal or other effects.

2.0 SITE SETTING

2.1 Site Location

2.1.1 The site is situated approximately 1.5km south west of Warrington town centre and may be located by Grid Reference SJ592872.

2.1.2 A site location plan is included in Appendix 1, Figure A1.1.

2.2 Site Description

2.2.1 At the time of the investigation the site comprised the north western edge of a larger agricultural field, extending off to the south east. The River Mersey lay to the north west, beyond a vegetated buffer, with unallocated land to the north east. Beyond the south western extent lay a roundabout and associated land on Forrest Way.

2.3 Geological Setting

2.3.1 Details of the geology underlying the site have been obtained from the British Geological Survey map, Sheet No. 97, ‘Runcorn’, solid and drift edition, 1:10,000 scale, published 1974, the Aecom Report and records provided by the BGS.

2.3.2 The records indicate the site to be underlain by superficial Tidal Flat Deposits, soft silty clays with layers of sand, gravel and peat.

2.3.3 The superficial deposits are underlain by the Wilmslow Sandstone Formation, part of the Sherwood Sandstone Group.

2.3.4 The closest historical borehole, located just north of the site in records provided by the BGS, indicates the Tidal Flat Deposits (formerly Alluvium) to be proven to a depth of 19.8m, overlying Glacial Till. The bedrock geology was not encountered.

3.0 SITE WORK

3.1 The site work was carried out between the 17th and 25th October 2016. The locations of exploratory holes have been planned, where possible, in general accordance with CLR 4, ref. 8.1 and the site work carried out on the basis of the practices set out in BS 10175:2011, ref. 8.2, BS 5930:2015, ref. 8.3, and ISO 1997:2007, ref. 8.4.

3.2 Ten boreholes, designated WS02B to WS12C, were undertaken by window sampler technique and forty-three trial pits, designated TP01A to TP12D, were dug by mechanical excavator at the positions shown on the exploratory hole location plan, Appendix 1, Figure A1.2. The depths of boreholes and trial pits, descriptions of strata encountered and comments on groundwater conditions are given in the borehole and trial pit records, Appendix 2.

3.3 The trial pit locations were set out on an approximate 25m grid in order to provide coverage across the site area, with window sample boreholes replacing approximately 25% of the pits in order to install gas and groundwater monitoring installations.

3.4 Representative disturbed samples were taken at the depths shown on the borehole and trial pit records. Sampling for environmental purposes included soil collected in amber glass jars which were retained in cool boxes with ice packs before being dispatched directly to the laboratory.

3.5 Standard penetration tests, refs. 8.6 & 8.5, were carried out in the boreholes in the various strata to assess the relative density or consistency. The values of penetration resistance are given in the borehole records.

3.6 Standpipes were installed in all boreholes, with response zones situated at varying depths throughout the Tidal Flat Deposits.

3.7 The ground levels at the borehole and trial pit locations, reported on the records, were surveyed on completion of works by Site Surveying Services to OS National Grid.

3.8 Groundwater and gas monitoring visits were undertaken on the 2nd and 17th November and 2nd December 2016, as detailed in Appendix 2.

4.0 LABORATORY TESTS

4.1 Geotechnical Testing

4.1.1 Geotechnical soil analysis was not specified as being required within the scope of work for this contract.

4.2 Chemical Testing

4.2.1 The suite of chemical analyses has been based upon a general suite of the more commonly occurring contaminants set out in Section 5.2 of the Aecom Report, in order to provide an initial overview of soil quality across the site.

4.2.2 The desk study for the wider site area indicated the possibility of contamination from offsite industrial sources, together with the likely disposal of sediment and material from river dredging on the site itself.

4.2.3 The chemical analyses were carried out on fifty-three soil samples and nine groundwater samples. The nature of the analyses is detailed below:

4.2.4 **Metals Suite** - arsenic, boron (water soluble), cadmium, chromium (total and hexavalent), copper, lead, mercury, nickel, selenium and zinc.

4.2.5 **Organic Suite** - petroleum hydrocarbons – TPH CWG speciated analysis, polycyclic aromatic hydrocarbons (PAH) – USEPA 16 suite, phenols (total monohydric).

4.2.6 **Inorganics Suite** - cyanide (total) and sulphate (water soluble).

4.2.7 **Others** - pH, organic matter content and asbestos.

4.2.8 The results of the soil testing are shown in Appendix 4, Test Reports 608104, 609133, 609136, 609380, 609384, 610279 and 611057. Results of the groundwater analyses are provided in Test Report 615787.

5.0 GROUND CONDITIONS ENCOUNTERED

5.1 Sequence

5.1.1 The sequence of the strata encountered during the investigation generally confirms the anticipated geology as interpreted from the geological map.

5.2 Topsoil

5.2.1 Very little in the away of Made Ground was encountered within the exploratory holes. Typically, the majority of locations showed grass over a sandy silt or silty sand topsoil, with varying amounts of clay.

5.2.2 Occasional anthropogenic fragments such as brick were observed, but there was nothing in any of the logs to indicate significant deposition of man-made dredging materials which may have been placed at the surface, the potential for which was identified within the Aecom report.

5.2.3 Topsoil thicknesses were relatively consistent across the site at approximately 0.3-0.5m, overlying Tidal Flat Deposits in all cases.

5.3 Tidal Flat Deposits

5.3.1 The superficial deposits were encountered underlying the topsoil in all exploratory hole locations to a maximum depth of 5.45mbgl.

5.3.2 All exploratory holes were terminated within superficial Tidal Flat Deposits.

5.3.3 As anticipated, the material varied in the proportion of the main expected constituents of clay, silt and sand, with peat and plant remains in many locations, at varying depths and often associated with relatively strong organic odours.

5.3.4 There was no evidence of staining or other odours which may be attributed to contamination of material from spills or other sources.

5.4 Groundwater

5.4.1 Groundwater was not encountered in any of the exploratory holes.

5.4.2 Groundwater was encountered as seepages across the site during the sitework, generally at depths ranging from 2.0m to 3.5mbgl, although was not observable in many locations.

5.4.3 Subsequent monitoring indicates varying depths of groundwater within the standpipes, generally within 0.5-1.5m of the surface, depending on the placement of the response zone and how cohesive the soils are.

6.0 ENVIRONMENTAL RISK ASSESSMENT

6.1 Contaminated Land

6.1.1 The definition of ‘contaminated land’, along with the relevant details on legislation and guidance is set out in Appendix 4.

6.2 Site History

6.2.1 The site is historically undeveloped and appears to have been primarily used for agricultural land. The proximity of the land to the River Mersey gives rise to the potential for the deposition and distribution of dredging sediments over time which may have impacted on soil quality, together with the presence of heavy industry in relatively close proximity to the site.

6.3 Risk Assessment – Human Health

6.3.1 The potential proposed development consists of mixed residential and as such, the risk assessment has been based on guidelines for a residential end use (with homegrown produce). Should the proposed development be changed in then further risk assessment should be undertaken, appropriate to the end use.

6.3.2 The results of the soil chemical analyses have been processed in accordance with recommendations set out in the CIEH and CL:AIRE document ‘Guidance on Comparing Soil Contamination Data with a Critical Concentration’, ref. 8.16. The results have been compared in the first instance to screening levels produced in accordance with current and best practice legislation and guidance, as detailed in Appendix 4.

6.3.3 Where the concentrations determined on site are at or below the respective screening level, they are considered not to pose a risk and are removed from further consideration, unless otherwise stated.

6.3.4 Those contaminants with observed concentrations above the screening levels are detailed below:

Location	**Depth (m)**	**Contaminant**	**Concentration (mg/kg)**	**Screening Level (mg/kg)**
Various	0.10 - 2.40	Arsenic	<100	37
		Lead	<480	200

6.3.5 In addition to the arsenic and lead detailed above, various polycyclic aromatic hydrocarbon (PAH) concentrations were slightly elevated above screening levels. Based on the conservative nature of the modelling and therefore the screening levels, these are not considered to warrant any further consideration and are not deemed to represent any significant risk to human health.

6.3.6 Of the fifty-three samples tested for arsenic, thirty-six exhibited concentrations elevated above the screening level of 37mg/kg, up to a maximum of 100mg/kg. The samples ranged in depth from 0.10m to 3.00mbgl. Elevated concentrations were observed at varying depths throughout the top 2.4m of soil.

6.3.7 Only six fewer samples exhibited elevated lead concentrations in relation to the screening level than arsenic, with a similar spatial distribution.

6.3.8 Further statistical analysis has not been undertaken at this time. A visual representation of the location of elevated lead and arsenic concentrations is provided in Figure A1.3, although this does not take into account the depth of the sample at each location.

6.3.9 In terms of the risks to human health, were residential redevelopment to take place on the site, remedial works may be required in order to negate the risks to end users from arsenic and lead. It is considered that further assessment should be undertaken at an appropriate point in time when more detailed development plans are available.

6.3.10 Further detailed statistical analysis, taking into account the various depths of samples, may assist in building up a more detailed picture, although this may require additional sampling to provide a sufficient dataset.

6.3.11 Detailed Quantitative Risk Assessment (DQRA) for each of the contaminants should be considered, with variables altered within the model to determine site specific assessment criteria, likely to be less conservative than the screening levels used within this initial assessment.

6.3.12 Should DQRA not provide sufficiently high enough screening criteria to avoid remedial works, it may be possible to zone the development into areas where no further assessment or remedial measures are required. Where this is not possible, it is likely that a simple capping layer would be adequate to negate any risk to end users. Alternatively, a less sensitive end-use could be considered, such as residential apartments where homegrown produce would not be a viable pathway.

6.3.13 It is possible, based on existing levels, that in order to facilitate development, levels on the site may need to be increased both from a flood protection and/or an engineering perspective. If so, this can be undertaken in conjunction with a remediation strategy incorporating a clean cover layer.

6.4 Risk Assessment - Controlled Waters

6.4.1 The site is located above a secondary undifferentiated aquifer (the Tidal Flat Deposits), overlying a Principal Aquifer (Wilmslow Sandstone Formation). The site is not within a groundwater source protection zone and there are three groundwater abstractions within 500m, the closest located approximately 250m to the west.