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SCIENCE CENTRAL ENABLING WORKS

Earthworks Completion Report
Hall Construction Services Limited

25/07/2014

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Signature				
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Science Central Enabling Works

Earthworks Completion Report
Hall Construction Services Limited

25/07/2014

Client

Hall Construction Services Limited

Consultant

WSP UK LTD
Weymouth House, Hampshire Court
Newcastle Business Park
Newcastle
NE4 7YG
UK

Tel: +44 (0)0191 298 1000
Fax: +44 (0)0191 298 1149

www.wspgroup.co.uk

Registered Address

WSP UK Limited
01383511
WSP House, 70 Chancery Lane, London, WC2A 1AF

WSP Contacts

Chris Lazenby
Brennig Davis

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1 Project Background

1.1 Introduction

1.1.1 The Science Central site, located at the former Newcastle Brewery site, Corporation Road, Newcastle upon Tyne, has recently undergone enabling works to create a building platform for planned redevelopment by Science Central LLP for mixed use including commercial and residential. The enabling works undertaken included:

- Removal of previously identified contamination hotspots;
- Localised demolition of below ground structures;
- Excavation of Made Ground and natural overburden to remove coal;
- Replacement and compaction of excavated material as engineered fill;
- Excavation, sorting and recompaction of Made Ground in areas outwith the coal extraction excavation;
- Provision of a 1.5m thick clean cover layer to all parts of the site (upper 500mm to be free of concrete fines); and,
- Drilling and grouting works out with the coal extraction area

1.2 Background Reports

1.2.1 The site was subject to several ground investigations, the results of which were used to produce the following documents, which should be read in conjunction with this report:

- Mott Macdonald Employers Requirements, ('*Science Central Enabling Works (inc. Coal Extraction'*), Employers Requirements', August 2012, Seventh Issue);
- WSP Specification for Earthworks ('*Science Central Enabling Works'*) February 2013, Issue 2; and,
- WSP Geotechnical Design Report ('*Science Central Enabling Works'*), July 2013 Revision 1.

1.2.2 This report includes all data previously reported in the following interim report:

- ('Science Central Enabling Works, '*Gateway Handover Area*, Earthworks Completion Report') July 2013, Issue 2.

1.2.3 The following reports have been completed in conjunction with this earthworks completion report, which address the remediation works carried out as part of the enabling works:

- WSP Remediation Completion Report ('*Science Central Enabling Works'*) July 2014; and,
- WSP Asbestos Monitoring Report ('*Science Central Enabling Works*') July 2014.

1.3 Scope of WSP Works

1.3.1 WSP UK Ltd (WSP) was appointed by Hall Construction Services Ltd (HCSL) to advise on the geotechnical elements of the engineering earthworks, including co-ordination of the site earthwork testing regime. This report covers the entire site which includes Site A, B and C. Site C was effectively incorporated as part of Site A during the enabling works as a revision to the site boundary once Site C became available.

1.3.2 The extents of the areas referred to in this report are as shown on **Figure MMD-283831-C-DR-00-XX-7001** in **Appendix B**. **Figure 1** in **Appendix B** highlights the various areas which were handed over in stages throughout the enabling works, to provide clarity to this report.

1.3.3 Full time geotechnical engineer attendance was provided by WSP during the works. Laboratory and field testing of the materials used in the earthworks was undertaken by HCSL's appointed sub-contractor, Ian Farmer Associates (IFA). The testing included classification tests (laboratory) for the materials used, along with compliance tests (in-situ) of the placed fills. The employer was represented full time on site by a representative from Mott Macdonald (MM).

1.3.4 Remediation works associated with treatment of mine shafts and mine workings are outside the scope of WSP's appointment and are summarised in records issued by the specialist grouting contractor and available from HCSL.

1.3.5 This report has been prepared for the use of HCSL and their agents and is not to be relied on by any third party without the written permission of WSP. A copy of our notes and limitations is provided as **Appendix A**.

1.4 Enabling Works Undertaken

1.4.1 The works undertaken by HCSL as part of the enabling works contract were undertaken between September 2012 and March 2014 and briefly comprised:

- Erection of site hoarding;
- Diversion of selected services;
- Installation and monitoring of gas and groundwater wells;
- Remediation of localised contamination hotspots;
- Stabilisation by drill and grout methods of worked coal seams outwith the coal extraction excavation;
- Removal of soil and rock overburden to enable extraction of coal from the area of proposed extraction;
- Removal of Made Ground materials down to natural strata in areas outwith the coal extraction excavation;
- Inspection of the base of all excavations for evidence of recorded or unrecorded mine shafts / adits;
- Filling, grouting and capping of mineshafts as required;
- Classification and compliance testing of excavated materials;
- Compaction trials of excavated material to develop backfill methodology;
- Placement and compaction of suitable site won materials as an engineered fill to the earthworks specification to make up levels back to a required profile;

- Placement of natural clean material, suitable for a residential end use, within upper the 1.5m of finished levels, including a 0.5m thick capping layer;
- Geotechnical assessment of high wall stability around the perimeter of the excavation; and,
- Monitoring of the gas/groundwater levels in the installations surrounding the excavations and groundwater sampling and subsequent chemical analysis.

Several variations to the works required were developed and agreed with the MM, as outlined in this report.

2 Earthworks Design

2.1.1 The Employer's Requirements (ERs) included outline requirements for earthworks elements of the scheme, summarised as follows:

- Unsuitable fills could not be used as backfill;
- Suitable fills could be used as backfill;
- Special Fill could be employed as capping layers;
- General Fill should be suitable fill and meet the following end product requirements:
  - Minimum degree of compaction – 95% maximum dry density (γ_{dmax}) [4.5 kg compaction for granular fills, 2.5kg* compaction for cohesive fills];
  - Maximum air voids content - 5% (4.5 kg compaction for granular fills, 2.5kg* for cohesive fills);
  - Minimum stiffness 15 MPa undrained*, 5 MPa drained (0.60* - 0.75m dia plate load test);
- Capping material shall comprise the upper 500mm of the finished level and shall meet the compaction requirements as for General fill and shall also have a minimum CBR of 20%.
- As an amendment to the ERs in Technical Query 11, it was clarified with MM that the end product requirements for general fill would be:
  - Average relative density to be >95% and no individual result to be below 90%;and
  - Average air voids to be <5% and no individual result to be above 10% (5% for cohesive Made Ground).

*Amended from ERs by subsequent agreement and Technical Query (TQ) 001, 10, 11 and 12 with MM. Relevant TQ responses are included as **Appendix H**.

2.2 Summary of Earthworks Specification

2.2.1 Full details of the method proposed for the earthworks and the compliance testing are provided within the WSP 'Earthworks Specification' which was prepared for the site to meet the requirements of the ERs and which was approved by MM.

2.2.2 The Earthworks Specification notes the various material types expected to be encountered in excavations and proposed to be used as engineered fill throughout the works.

2.2.3 All fills were to be subject to a series of Classification/acceptability tests to confirm the properties of each class of material. Classification/acceptability test samples were to be undertaken from the various stockpiles or at the point of excavation or recompaction of each class of material.

2.2.4 Compaction trials were to be undertaken to establish an appropriate compaction method (plant / number of passes / layer thickness etc) for the materials used as engineered fill.

2.2.5 Compliance tests were to be undertaken on the engineered fills once placed and compacted to demonstrate degree of compaction achieved.

2.2.6 The Earthworks Specification prepared by WSP for the works outlined classification tests on the general fill to be carried out at the following frequency:

- Particle Size Distribution (PSD): 1 per 5,000 m^3;

- Optimum moisture content (OMC), dry density (4.5kg or 2.5kg compaction): 1 per 5,000 m^3 up to a maximum of 5 samples per material type;
- Moisture content (MC): 1 per 5,000 m^3;
- Plasticity Index (PI): 1 per 5,000 m^3 (cohesive soils only).

2.2.7 Compliance tests on the general fill were to be carried out at the following frequency:

- Nuclear Density Test (NDT) / core cutter – 1 per 1,125 m^2 for each 500mm thickness of fill placed;
- Sand Replacement Test (SRT) - 1 per 11,250 m^2 for each 500mm thickness of fill placed;
- Plate bearing test (PBT) – 1 per 10,000m^2 for each 500mm thickness of fill placed;
- CBR (California Bearing Ratio) capping layer only – 1 per 4,000 m^2 for each 500mm thickness of fill placed.

2.3 Mineshaft Inspections

2.3.1 Ten mine shafts are reported to be present across the site in the ERs, (based on Coal Authority records and other sources). As part of the enabling works, all shafts remaining after coal extraction were required to be filled, grouted and capped (by others). The risk of unrecorded shafts being present was to be addressed by inspection of the exposed surface of natural strata in all excavations after removal of Made Ground cover and/or natural overburden. This inspection was to be carried out jointly by HCSL and the WSP geotechnical engineer immediately after exposure of natural strata and prior to placement of any backfill. Any ground disturbance, structures or other evidence of possible unrecorded mineshafts was to be subject to further investigation as required by HCSL.

3 Earthworks

3.1 General Details

3.1.1 Earthwork operations were undertaken between October 2012 and March 2014 and comprised the following main elements:

- Excavation to the base of the Metal Seam including recovery of available coal and subsequent backfilling with engineered fill in Site A; and,
- Reduced level excavation down to the top of the natural strata (Glacial Till or Rock) and subsequent upfilling to the required levels with engineered fill in Site B and C and the area out with the coal extraction in Site A.

3.1.2 The extent of the excavation, backfilled earthworks levels and location of excavation high wall are shown on **Figure 2** and **Figure 3** in **Appendix B**.

3.1.3 The combined plan area of Site A and C is approximately 75,000m^2. The plan area of Site B is approximately 10,000m^2. The total volume of engineered fill placed within the opencast backfill and the surrounding areas was estimated to be approximately 642,500m^3.

3.1.4 A series of photographs showing key stages throughout the enabling earthworks are presented as **Appendix B**.

3.2 Materials Used in Earthworks

3.2.1 The following materials were used in the engineered earthworks throughout the site:

- General engineered fill comprising predominantly crushed siltstone and sandstone (referred to as fine grained rock) and weathered mudstone with lesser proportions of Cohesive Made Ground and Glacial Till. Limited volumes of Granular Made Ground and High Post Sandstone were also used. Cohesive Made Ground with high coal content was placed sparingly in the north east region of the site. Pre existing site stockpiles of Recycled Aggregate (6F2) was re-used around the site. An extremely limited volume of site generated Processed Demolition Rubble was used as engineered fill.
- The clean cover layer comprised sandy Siltstone / silty Sandstone, Weathered Mudstone, Glacial Till and a limited volume of High Post Sandstone in the north east region.
- The capping layer predominantly comprised crushed sandstone or siltstone (FGR).

Due to the working method adopted and the placement of engineered fill in a series of small backfill zones within individual cuts, precise records of volumes and locations of various materials placed are not available, although approximate values are indicated in Table 3.1.

3.3 Classification Tests Undertaken

3.3.1 The following classification tests have been undertaken on the materials used as engineered fill. Results of all these tests are summarised in **Appendix C** and test certificates presented in Volume 2.

Table 3.1 – Classification Testing Undertaken

Material Type	Particle Size Distribution	Moisture Content	Dry Density / Moisture Content	Los Angeles Coefficient	Particle density	Estimated Volume (m^3)
Fine Grained Rock (FGR)	44 (56)	37(56)	8 x 4.5kg (5)	6*	8	280,000
Weathered Mudstone (WM)	19 (20)	17 (20)	8 x 4.5kg (5)	-	9	100,000
Glacial Till (GT)	13 (8)	8 (8)	3 x 4.5kg 4 x 2.5kg (5)	-	6	40,000
Recycled Aggregate (RA)	12 (7)	10 (7)	5 x 4.5kg (5)	4	5	35,000
Cohesive Made Ground (CMG)	19 (18)	20 (18)	8 x 4.5kg 7 x 2.5kg (5)	-	10	95,000
Cohesive Made Ground with coal (CMG)	2 (3)	23 (3)	2x 2.5kg (3)	-	2	15,000
Processed Demolition Rubble (PDR)	2 (1)	2 (1)	2 x 4.5kg (1)	-	2	5,000
Silty Clay (SC)	1	2	1 x 2.5kg	-	1	<1,000
Weathered Coarse Grained Rock (WCGR)	6 (4)	6 (4)	6 x 4.5kg (4)	-	6	20,000
Granular Made Ground (GRMG)	4 (2)	4 (2)	2 x 4.5kg (2)	-	2	7,500
Fine Grained Rock Capping Layer (FGR)	19 (8)	18 (8)	5 x 4.5kg (5)	2*	4	45,000
Total	**141 (127)**	**147 (127)**	**60 (40)**	**8**	**54**	**642,500**

*For capping layer only.

Figures in brackets show the total number of tests required to meet the testing frequency outlined in the Earthworks Specification. It can be seen that some deviation from these quantities occurred for specific material types, although the minimum overall frequency of testing has been maintained. This deviation is mainly due to ensuring testing was targeted to materials demonstrating potential for most variability during the works.

3.4 Compaction Trials

3.4.1 Compaction trials were carried out on the main material types used as engineered fill. Summary results of these trials are presented as **Appendix D**. The results of these trials were used to assess the appropriate layer thickness (taken from SHW 600 for corresponding material classification) and compactive effort could achieve the target in situ density and stiffness for the individual material

types. No testing was carried out on the Granular Made Ground due to the low quantity of material utilised.

3.4.2 Compaction trials were undertaken either outwith the excavation or were incorporated as part of an engineered fill layer. Each compaction trial was approximately 5m x 10m and placed using a tracked dozer and compacted using a vibratory roller (see section 3.4.3). Each compaction trial was placed at the thickness identified in Table 3.2 and tested using the NDG after every two passes. NDG testing was carried out in a number of different areas within the compaction layer and an average was calculated. The process was repeated after every two passes and results were used to create the data presented in **Appendix D**.

3.4.3 These trials indicated the following compaction method to be appropriate for the various material types used as engineered fill. In all cases the compaction plant used in the trials was a smooth wheeled vibratory roller of > 5000 Kg per metre width (18,800kg mass single drum roller 2.1m width, i.e. Ref no 10 as specified on Table 6/4 of SHW 600). This plant was utilised throughout the works to provide compaction.

Table 3.2 – Summary of Compaction Trial Data

Material Type	Uncompacted Layer thickness (mm)	Number of passes
Fine Grained Rock – FGR	500	6
Weathered Mudstone – WM	350	6
Glacial Till - GT	300	6
Recycled Aggregate - 6F2	300	6
Cohesive Made Ground – CMG	250	6
Cohesive Made Ground with Coal CMG w coal	250	6
Processed Demolition Rubble – PDR	300	6
Weathered Coarse Grained Rock - WCGR	400	6
Fine Grained Rock (Capping) – FGR	250	6

3.5 Compliance Tests Undertaken

3.5.1 In situ compliance tests were carried out on the engineered fill. Results of these tests are summarised and presented in **Appendix E**. The positions of these tests are shown on **Figure 4** in **Appendix B**.

3.5.2 Table 3.3 below summarises the compliance tests carried out. The figures in brackets indicate the total number of tests required to comply with the frequency outlined in the Remediation Method Statement. Retests subsequent to initial non-compliant test results are not included in these totals.

Table 3.3 – Summary of Compliance Testing Undertaken

Material Type	Nuclear Density Testing (NDT)	Sand Replacement Testing (SRT)	Plate Bearing Test (PBT)	California Bearing Ratio (CBR)[1]	Estimated Volume (m^3)
Fine Grained Rock (FGR)	536 [498]	53[50]	69[56]	3[0]	280,000
Weathered Mudstone (WM)	258[178]	22[18]	30[20]	-	100,000
Glacial Till (GT)	63 [71]	6[7]	10[8]	-	40,000
Silty Clay (SC)	1	0	0		<1,000
Recycled Aggregate (RA)	68[62]	4[6]	5 [7]	-	35,000
Cohesive Made Ground (CMG)	147[169]	20 [17]	9[19]	-	95,000
Cohesive Made Ground w/ coal (CMG)	24[27]	5 [3]	1[3]	-	15,000
Processed Demolition Rubble (PDR)	1[9]	0[1]	0[1]	-	5,000
Weathered Coarse Grained Rock (WCGR)	20[36]	2[4]	4[4]	-	20,000
Granular Made Ground (GRMG)	12[13]	1[1]	-	-	7,500
Fine Grained Rock Capping Layer (FGR)	60 [80]	8[8]	5[9]	20[20]	45,000
Total	1190[1143]	121 [114]	133 [127]	23[20]	642,500

[1] CBR tests are required for the capping layer only (ie final 500mm of filling).

Figures in brackets show the total number of tests required to meet the testing frequency outlined in the Earthworks Specification. It can be seen that some deviation from these quantities occurred for specific material types, although the minimum overall frequency of testing has been maintained. This deviation is mainly due to ensuring testing was targeted to materials demonstrating potential for most variability during the works.

3.6 Observations during Earthworks

3.6.1 During the earthworks regular observations were made by the Geotechnical Engineer. The following key observations of the earthworks were made during that time.

During excavation works:

- Excavation commenced in cut 1 (south east corner) and extended progressively west, spiralling to the north to finish in the north east corner, in a series of open cuts, backfilled in stages once coal had been removed. At any one time, between 1 and 3 cuts were open or partially backfilled. Whilst the excavation progressed in general accordance with the numbering on the cuts on **Figure FB/CA/GWM/1 No.4** , it should be noted that the cuts were not treated as individual excavations;
- Across the majority of the site there were frequent obstructions encountered within the excavation, mainly comprising concrete basements (the majority being reinforced), foundations and brick work. Along the south of Site A (Cuts 1-4) a reinforced concrete basement wall and floor was present which partially extended below Corporation Street. It was agreed with MM that the basement would remain intact so there would be no detrimental effect on the stability of that road. The basement walls were locally broken out to approximately 1m below new ground level where possible to do so and is shown on a HCSL drawing;
- The cohesive Made Ground overlying the Glacial Till and bedrock was heavily disturbed throughout the site with fragments of concrete, remnants of brick walls, concrete foundations and basements;
- Segregation of material types arising from the cuts was carried out by HCSL. Generally, the material types were stockpiled separately as Fine Grained Rock, Cohesive Made Ground, Glacial Till, Recycled Aggregate and Weathered Mudstone and the mixing of materials was avoided;
- The works carried out by Groundshire Ltd resulted in mixing of materials due to the excess grout that was spread across the surface of the site and percolated through the granular material. Further information on this material is listed in Section 4.4.3.
- Wet cohesive material was predominantly placed on the top of the stockpiles to encourage drying during the summer months. Occasionally, during periods of dry weather, an excavator would re work the wetter clay and move the material to aid the drying out process; and,
- In addition to the classification and compliance testing, the earthworks were subject to daily observations in order to visually assess the material used and the effectiveness of the compactive effort. Cohesive material which appeared to show excessive deformation or rutting during compaction was removed and placed in on-site stockpiles to enable drying prior to re-use on future phases, or HCSL were instructed to place the material as a 200mm thin layer between layers of granular fill.

Groundwater:

- To reduce the build-up of water on the working surface, backfilling progressed with a slight fall towards a sump. A high powered groundwater pump was utilised to control the standing water level within the cut to ensure fill was not placed in standing water. As the cuts progressed, the groundwater pump was moved to the deepest point of the excavation to control standing water;
- Where groundwater seepages or surface water caused localised softening of the placed fills, the wetted layer of material was typically removed before backfilling recommenced. The removed materials were placed in on-site stockpiles to enable drying prior to re-use on future phases as required. Wherever practicable, a layer of granular material was placed over cohesive layers in an alternating pattern;

During coal recovery works:

- The two expected coal seams (High Main and Metal (Upper and Lower)) were generally heavily worked, with workings found to be loosely backfilled with clay, mudstone, collapsed strata or locally grouted. Within the Metal seam there was very little evidence of significant open voids as the heavily fractured thin band of sandstone above the seam had often collapsed. However, within the High Main seam and more regularly in the overlying High Main Post Sandstone, frequent voids of varying sizes were encountered during excavation;
- Daily observations of the base of excavations were undertaken to identify any evidence of unrecorded mine shafts. Occasionally, areas were exposed and backfilled over a weekend and validation could not be completed by a WSP engineer, in which case, the HCSL site foreman undertook these inspections on his own and recorded his findings (see Section 6);

High wall stability/strata:

- Ground conditions throughout the site were variable, as expected, but generally corresponded to the conditions encountered in previous site investigations. The excavated material comprised Recycled Aggregate (stockpiled and present as a surface layer), Cohesive Made Ground, Glacial Till (stiff clay), Weathered Mudstone and FGR (Silty sandstone) and High Post Sandstone in the north and west. The two coal seams encountered were the Metal (split seam separated by weathered mudstone) and the High Main. Occasional pockets of granular Made Ground were encountered, particularly in Site C and occasional glacial channels cut down into the bedrock;
- In weak rock and superficial strata, benches were cut into the high wall at an approximate gradient of 1h:2v at approximately 1m height intervals, generally as outlined in the method statement. Cutting of benches at the proposed 1m intervals into the high wall in stronger siltstone or sandstone strata was considered impractical by HCSL and these were generally excavated to the required profile of 1h:2v without benches; and,
- Generally the excavation side walls remained generally stable throughout the works. Within cut 5/6, a Glacial Till channel was observed to extend nearly to the base of the excavation. A series of tension cracks were noted at the crest of the excavation before reaching the Metal Coal Seam, suggesting potential instability. Measures were taken to reduce the weight at the crest of the high wall by removing the Made Ground fill (approximately 2.5m thick) and backfilling of the excavation commenced immediately around this area to add weight to the bottom of the batter;

Backfilling:

- Material was spread in layers using the D6, D8 or D9 tracked blades at the required thickness up to 500mm thick and compacted with at least six passes of the compaction plant (smooth wheeled vibratory roller class 10). Occasionally, more than six passes were required to break down oversized particles;
- As backfilling progressed in relatively small areas in many cuts, ‘loose’ edges remained on the edge of the previously compacted layer. The loose edges comprised some oversize material cast to the edge of the previous backfilled layers, and a narrow wedge of un compacted fill which could not be rolled. When placing new fill alongside the previous fill, this loose material was cut back with the tracked blade and incorporated into the new fill layer so that no fill remains uncompacted. This was achieved in the majority of the areas witnessed;
- Due to the rapid rate of upfilling in some areas, especially where small areas where backfilled, the results of compliance tests were not available until several additional layers of fill had been placed. This was particularly the case for SRTs which had a reporting delay of approximately 48 hours or more on more than one occasion. For this reason it was not always possible to apply rectification procedures when a non-compliant test results was reported, and in some instances an alternative test was carried out (eg. plate load test) to confirm acceptable compaction was

achieved. Furthermore, as the third party testing technician was not on site full time, it was not possible to obtain a re-test in all cases when further compaction was applied, following a non-compliant initial test result. To maintain progress rates, HCSL decided to continue filling and use the results of subsequent testing to assess the likelihood that the additional compaction had achieved the desired effect;

- The stronger FGR excavated and used as engineered fill was typically blocky prior to compaction, with frequent boulder sized particles in excess of 330mm (the maximum dimension permitted in engineered fills - i.e. 2/3 of the layer thickness of 500mm). This material was trafficked several times during deposition to break down the oversized particles as far as practicable, although some oversize particles remain in the rock fill in many areas, generally no greater than 500mm in the maximum dimension. To remedy this issue, stronger rock was processed and crushed after it became apparent that an excess of oversize particles could remain after deposition. It should be noted that crushing of the rock was not carried out prior to August 2013. The majority of areas where oversized particles are present in the south and west of the site (cuts 5-9, 18), becoming rare in the north and east region;
- Where cohesive material was placed wet of optimum moisture content during wet weather, generally four passes were applied so that the required compaction was achieved without overworking leading to degradation. In extreme cases, the material would be placed in thinner layers and compacted with four passes;
- A material was encountered below the High Main Coal seam (silty clay with high coal content). This material proved difficult to compact so was stockpiled during the summer months to enable drying (subsequently classified as Cohesive Made Ground with coal);
- As the earthworks neared completion, the materials remaining on site available for use as backfill were predominantly Sandstone and cohesive Made Ground. As a result of this, the north east area (cuts 15, 16 and the north of cuts 12 and 13) are backfilled with higher proportions of cohesive fill compared with other areas of the site. Endeavours were made to place the cohesive fill in thinner layers and ‘sandwiched’ between layers of granular rock fill;
- Endeavours were made throughout the enabling works to ensure a reasonable distribution of cohesive and granular material was placed across the site.

4 Results of Classification Testing

4.1.1 All classification test results are included as **Appendix C1 – C10**. The results are summarised in the tables below for individual material types used as engineered fill.

4.2 Summary of Results of Classification Tests on Fine Grained Rock Fill (FGR)

4.2.1 Results of classification tests for the FGR material are presented as **Appendix C.1** and summarised in Table 4.1.

Table 4.1 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	8	Maximum Dry Density (MDD): Range = 1.79 – 2.22 Mg/m^3. Average = 2.04 Mg/m^3. OMC: Range = 6.1-14%. Average = 9%
Particle Size Distribution	44	27 of the samples indicate Class 1C grading, 14 indicate Class 1B and three samples indicate Class 2C.
Moisture Content	37	Range = 4 - 19% Average = 8%
Particle Density	8	Range = 2.59 – 2.7 Mg/m^3 Average = 2.65 Mg/m^3
LA Coefficient* (Siltstone)	6	Range = 33 – 40% Average = 36%

* LA Coefficient testing was not a requirement of the ERs. Testing was carried out and reported here at the request of MM to determine its suitability for use as capping material.

4.2.2 This material was typically excavated as cobble through to large boulder sized fragments, particularly coarse where the rock was stronger. The rock was increasingly difficult to excavate and process to a suitable fill material, so a series of techniques were utilised to break down the material. When the rock was in situ it was broken by a hydraulic 'pecker' or ripped by an excavator. It was then broken further by constant lifting and breaking by excavators and processed by mechanical crushers where required.

4.2.3 The results indicate that the majority of the FGR fill after compaction was Class 1C or 1B. Three samples tested indicated a Class 2C grading.

4.2.4 During deposition and compaction, the FGR was subject to tracking and further breakdown. Once compacted, the material generally comprised sand through to large cobbles with some (typically 5-20%) boulder sized fragments. The presence of such boulders is not represented in the test results, as the sampling method employed by IFA tended to omit sampling of the very large fractions.

4.2.5 The three samples which recorded a 2C grading (stony cohesive material) are not considered to be a representative sample of the material which has been compacted. It is likely that those samples were taken from the surface of the rock fill which had been trafficked on numerous occasions with the rock breaking down and containing more than 25% of clay/silt sized particles in the near surface material.

4.2.6 The wide variation of natural moisture contents of this material was considered likely to be due to the handling of the material. As the silty sandstone was extracted, broken down, stockpiled, tracked and

compacted, the material became generally finer and absorbed more water during periods of heavy rainfall.

4.2.7 The average Natural Moisture Content (NMC) was within the range of the optimum moisture content OMC.

4.3 Summary of Results of Classification Tests on Weathered Mudstone (WM) Fill

4.3.1 Results of classification tests for the fine weathered mudstone material are presented as **Appendix C.2** and summarised in Table 4.2.

Table 4.2 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	8	Maximum Dry Density MDD: Range = 1.88 – 2.08 Mg/m^3, Average = 2.03 Mg/m^3 OMC: Range = 7-11%, Average = 9%
Particle Size Distribution	19	Thirteen of the samples indicate a Class 1B grading, one indicates a class 1C and five indicate a class 2C.
Moisture Content	17	Range = 5 - 12% Average = 8%
Particle density	8	2.35 – 2.66 Mg/m^3. Average = 2.57 Mg/m^3

4.3.2 The results show that the weathered mudstone demonstrated a varying range of grading classification once compacted. This material was typically excavated as gravel to small boulder sized fragments and was deliberately broken down during spreading and compaction. Once compacted, the material comprised sandy gravel with cobbles and variable clay content, often high enough to classify as a Class 2C material. The average NMC was within the range of the OMC.

4.4 Summary of Results of Classification Tests on Glacial Till (GT) Fill

4.4.1 Results of classification tests for the fine weathered mudstone material are presented as **Appendix C.2** and summarised in Table 4.3.

Table 4.3 – Summary of Classification Tests

Glacial Till	Number of tests	Results
4.5kg Compaction Tests	3	Maximum Dry Density MDD: Range = 1.97 – 2.02 Mg/m^3, Average =2.00 Mg/m^3 OMC: Range = 8 - 10%, Average = 9%
2.5kg Compaction Tests	4	Maximum Dry Density MDD: Range = 1.85-2.03 Mg/m^3, Average = 1.92 Mg/m^3 OMC Range 9.6 - 12% (average 11%)
Particle Size Distribution	13	All tests demonstrate a 2C grading.
Moisture Content	8	Range = 7-26%. Average = 13%

Particle density	6	Range= 2.6 – 2.68Mg/m^3 Average 2.64Mg/m^3
Plasticity Index	7	Range = 15 - 21% Average = 18%

4.4.2 The average NMC was slightly higher than the range of the OMC for testing carried out in the 2.5kg compaction method.

4.5 Summary of Results of Classification Tests on Recycled Aggregate (RA) Fill

4.5.1 Results of classification tests for the recycled aggregate material are presented as **Appendix C.3** and summarised in Table 4.4.

4.5.2 The Recycled Aggregate was the material present upon mobilisation to site in a stockpile and the 300mm (approximate) surface layer. In the WSP Earthworks Specification, this material is referenced as Processed Demolition Rubble. A different separate material type has been generated on site referenced processed demolition rubble from break out and processing of onsite obstructions (see Section 4.7).

Table 4.4 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	5	Maximum Dry Density MDD: Range = 1.81 -1.88 Mg/m^3, Average = 1.84 Mg/m^3 OMC: Range = 12-14 %, Average = 13%
Particle Size Distribution	12	Ten samples indicate a Class 6F2 grading and one indicates a Class 2C.
Moisture Content	10	Range = 10 -17% Average = 13%
Particle density	5	Range = 2.49 – 2.58 Mg/m^3 Average = 2.55 Mg/m^3
LA Coefficient	4	Range = 38-40% Average = 39%

4.5.3 The results show the majority of the samples were Class 6F2 grading and one a Class 2C. The one result of 2C grading was considered likely to be a result of the mixing of 6F2 with underlying cohesive made ground as the materials were often difficult to segregate during excavation. The average NMC is within the range of the OMC.

4.5.4 To investigate the effect of the surface layer of 6F2 Recycled Aggregate contaminated by grout from the mine workings consolidation operation, additional classification testing was carried out. A sample was taken for 4.5kg compaction, a PSD and moisture content to determine the material properties. The sample had indicated a maximum dry density of 1.8 Mg/m^3 and a slightly higher MC than the uncontaminated Recycled Aggregate. It was agreed with the MM that the 6F2 Recycled Aggregate criteria could also be adopted for this material where contaminated with grout.

4.6 Summary of Classification Results of Tests on Cohesive Made Ground (CMG) Fill

4.6.1 Results of classification tests for the cohesive Made Ground material are presented as **Appendix C.4** and summarised in Table 4.5.

Table 4.5 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	8	Maximum Dry Density MDD: Range = 1.82- 2.01 $Mg/m^{3,}$ Average = 1.95 Mg/m^3 OMC: Range = 8 -11%, Average = 9%
2.5kg Compaction Tests	7	Maximum Dry Density MDD: Range = 1.77 – 1.91 Mg/m^3, Average = 1.81Mg/m^3 OMC: Range = 10 -14%, Average = 13%
Particle Size Distribution	19	All tests indicate a Class 2C grading.
Moisture Content	20	Range = 12-23%. Average = 16%
Particle density	10	Range = 2.44 – 2.65 Mg/m^3 Average= 2.55 Mg/m^3
Plastic limit	11	Range = 10 – 25% Average = 21%

4.6.2 Testing on the Cohesive Made Ground was undertaken using both a 2.5kg hammer and a 4.5kg hammer based on the response to Technical Query 10 (TQ) from MM, which concludes that the 2.5 kg result should be used for compliance purposes. The average NMC is typically wet of the range of OMC obtained from the 2.5kg tests.

4.7 Summary of Results of Classification Tests on Cohesive Made Ground with Coal Fill

4.7.1 Results of the classification tests for the cohesive Made Ground with Coal material are presented as **Appendix C.5** and summarised in Table 4.6.

Table 4.6 – Summary of Classification Tests

Test	Number of tests	Results
2.5kg Compaction Tests	2	Maximum Dry Density MDD: Range = 1.63 – 1.71 Mg/m^3, Average = 1.67 Mg/m^3 OMC: Range = 7-12%, Average = 9.4%
Particle Size Distribution	2	Both tests indicate a Class 2C grading.
Moisture Content	23	Range = 10 - 19%. Average = 15%
Particle density	2	2.08-2.18 Mg/m^3 Average 2.13 Mg/m^3

4.7.2 Mine workings backfill, areas of disturbed outcropping strata and ground disturbance resulted in the above material type of variable provenance, but characterised as a Cohesive Made Ground with variable and often high coal or coal fines content.

4.7.3 The high number of moisture contents taken was due to the sensitivity and variability of this material when used as backfill as a result of the high coal content.

4.7.4 The average NMC is typically higher than the range of the OMC.

4.8 Summary of Results of Classification Tests on Processed Demolition Rubble (PDR) Fill

4.8.1 Results of the classification tests for the processed demolition rubble material are presented as **Appendix C.6** and summarised in Table 4.7.

Table 4.7 – Summary of Classification Results

Test	Number of tests	Results
4.5kg Compaction Tests	2	Maximum Dry Density MDD: Range = 1.95 – 1.98 Mg/m^3, Average = 1.97 Mg/m^3 OMC: Range = 10 %, Average = 10%
Particle Size Distribution	2	Both tests indicate a 1C grading.
Moisture Content	2	Both results were 13%.
Particle density	2	2.6 – 2.61 Mg/m^3 Average 2.60 Mg/m^3

4.8.2 The average NMC was 3% above the average OMC.

4.9 Summary of Results of Classification Tests on Silty Clay Fill

4.9.1 In late June 2013 a slightly different glacial drift deposit was encountered during the excavation works in Site B. Initially, the material type was identified as a particularly silty variation of the Glacial Till and the corresponding Glacial Till target density was adopted for compliance testing. The volume of the material was very small (<1000m^3). The material was subject to classification tests including a

compaction test (2.5kg) to obtain a representative target density. The result is listed in Table 4.8 below.

Table 4.8 – Classification testing result

Test	Number of tests	Results
2.5kg Compaction Tests	1	Maximum Dry Density MDD: Single result = 1.91 Mg/m^3 OMC: 13%
Particle Size Distribution	1	Class 2C grading.
Moisture Content	2	Range = 8-13%. Average = 11%
Particle density	1	Single result = 2.75 Mg/m^3

4.9.2 The NMC was the same as the OMC.

4.10 Summary of Results of Classification Tests on Weathered Coarse Grained Rock (WCGR) Fill

4.10.1 Results of the classification tests for the WCGR material are presented in Appendix **C.8** and summarised in Table 4.9.

Table 4.9 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	6	Maximum Dry Density MDD: Range = 1.99 – 2.08 Mg/m^3, Average = 2.03 Mg/m^3 OMC: Range = 7-10%, Average = 8%
Particle Size Distribution	6	Three of the tests indicate a Class 2C and two indicate a Class 1B. One test is close to the grading requirements of Class 1C but contains slightly more fines (<63mm) than required (<15%).
Moisture Content	6	Range = 9-13%. Average = 11%
Particle density	6	Range = 2.46 – 2.69 Mg/m^3 Average 2.57 Mg/m^3

4.10.2 The properties of the WCGR varied throughout the works depending on the degree of weathering and general disturbance of the material. The High Post Sandstone was often weak and broke down during the excavation and handling processes. As such, once the material was trafficked, placed and compacted, the properties of the material often represented a sandy cohesive fill, ranging from a Class 1C to a Class 1B to Class 2C. The average NMC is slightly wet of the range of OMC.

4.11 Summary of Results of Classification Tests on Granular Made Ground (GRMG) Fill

4.11.1 Results of the classification tests for the GRMG material are presented in **Appendix C.9** and summarised in Table 4.10.

Table 4.10 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	2	Maximum Dry Density MDD: Range = 1.96 -2.01 Mg/m^3, Average = 1.985 Mg/m^3 OMC Range 8.7-9.4% (average 9.1%)
Particle Size Distribution	4	Two samples indicate a Class 1C grading, one shows a Class 6F2 and one a Class 1B grading.
Moisture Content	4	Range = 5-13%. Average = 9%
Particle density	2	Range = 2.61-2.65 Mg/m^3 Average= 2.63 Mg/m^3

4.11.2 The average NMC is typically within the range of the OMC.

4.12 Summary of Results of Classification Tests on Fine Grained Rock (Capping Layer) (FGR) Fill

4.12.1 Results of the classification tests for the FGR material are presented in **Appendix C.10** and summarised below.

Table 4.11 – Summary of Classification Tests

Test	Number of tests	Results
4.5kg Compaction Tests	5	Maximum Dry Density MDD: Range = 2.06- 2.16 Mg/m^3, Average = 2.11 Mg/m^3 OMC: Range = 7-8.5 %, Average = 7.5%
Particle Size Distribution	19	14 samples indicate a Class 6F2 grading and five indicate a Class 1C grading.
Moisture Content	18	Range = 4-9%. Average = 7%
Particle density	4	Range = 2.47-2.65 Mg/m^3 Average = 2.6 Mg/m^3
LA Coefficient	2	Range 40-49% Average = 44.5%

4.12.2 This material comprises FGR material that was too coarse to be compacted once excavated and needed further processing to be placed as a compliant fill. The material was crushed using a mechanical crusher intended to achieve a Class 6F2 classification. Occasionally, due to rare exceedences of oversize fragments, a Class 1C was obtained after processing.

4.12.3 The average NMC was typically below the range of the OMC.

4.13 Conclusion of Classification Tests

4.13.1 Approximately 642,500m^3 of engineered fill material has been placed and compacted. The frequency of classification tests has been completed in general accordance with the requirements of Table 1/5 **Appendix** 1/5 of the Specification.

4.13.2 A notable exception to this is the frequency of testing carried out on the FGR. The FGR was also crushed for use as capping and at the time of crushing / sampling, the final use of the stockpiled processed FGR was not certain. The 'shortfall' in testing of the FGR (when used as general backfill) is compensated by the extra testing carried out on this same material when alternatively used as FGR capping.

4.13.3 The results of the classification tests indicate that fills used across the site generally met the relevant grading and moisture content requirements set out in **Table 6.1 Appendix 6/1** of the Earthworks Specification. However, observation of the placed fills indicated that in some instances where strong siltstone / sandstone rock fill was used, particles exceeding the maximum particle size permitted for that class of material and exceeding the 2/3 loose layer thickness (330mm) criteria remained after spreading and compaction. These boulders are typically tabular, being generally 500mm and very rarely up to 1000mm in largest dimension and 150- 300mm in the smallest dimension and could represent between approximately <5% to 20% of the fill mass in some layers.

4.13.4 On the basis of the classification tests carried out the following representative Maximum Dry Density (MDD) values were selected for the various materials used as engineered fill. These values varied as the works progressed, as new test data became available and the representative MDD values used is based on an average of all the test data available at the time.

Table 4.12 – Summary of the Average Maximum Dry Density used During Enabling Works

Material	**Representative MDD Throughout Enabling Works (Mg/m^3)**						
Approximate Period	Jan 2013	Feb – Mar 2013	Mar-May 2013	May-Jul 2013	Jul-Sep 2013	Sep-Dec 2013	Dec-April 2013/4
Fine Grained Rock (FGR)	2.095	2.04	2.04	2.04	2.04	2.04	2.04
Weathered Mudstone (WM)	2.05	2.05	2.055	2.05	2.05	2.02	2.02
Recycled Aggregate (RA)	1.825	1.84	1.84	1.84	1.84	1.84	1.84
Cohesive Made Ground (CMG)	1.8	1.8	1.8	1.8	1.82	1.80	1.81
Processed Demolition Rubble (PDR)	-	-	1.96	1.96	1.96	1.96	1.96
Glacial Till (GT)	1.87	1.87	1.87	1.87	1.9	1.94	1.92
Weathered Coarse Grained Rock (WCGR)	-		2.04	2.04	2.04	2.04	2.03
Granular Made Ground (GRMG)	-		-	-	1.98	1.98	1.98

Sandstone Capping Layer (FGR) capping	-		-	-	-	2.06	2.12-2.11
Cohesive Made Ground with Coal (CMG) w/coal	-		-	-	-	1.67	1.67

- Material not used during this period.

5 Results of Compliance Testing

5.1.1 All compliance test results are summarised and presented in **Appendices E1- E10**. The locations of these tests are shown on **Figure 4** in **Appendix B**.

5.1.2 A summary of non-compliant results and the rectification subsequently carried out are presented as **Tables F1-F5** in **Appendix F**. It is noted that rectification was generally not carried out when calculated air voids exceeded the 10% air voids target value before April 2013, due to discussions on air voids targets from January 2013 which was not formally clarified by MM until 24 April 2013 by way of response to TQ 11.

5.2 Results of Nuclear Density Gauge Tests (NDG)

5.2.1 Results of the NDG testing are summarised in **Table 5.1**, below.

Table 5.1 – Summary of NDG Tests

Material	Number of tests	Results (relative density)	Air Voids (%)
Fine Grained Rock (FGR)	585(49)	Range = 91.20 - 104.40% Average = 97.30 %	Range = -11.90 – 16.80% Average = 6%
Weathered Mudstone (WM)	290 (32)	Range = 92.20 – 110.50 % Average = 96.5 %	Range = -8.80 – 11.6% Average = 2.60%
Recycled Aggregate (RA)	74(6)	Range = 92.60 – 110.70 % Average = 98.20 %	Range = -5.20 – 10.90% Average = 4.30%
Cohesive Made Ground (CMG)	155(8)	Range = 92.20 – 111.50 % Average = 100.60 %	Range = -11 – 10.20% Average = 0.80%
Processed Demolition Rubble (PDR)	2(1)	93.60 % (Single result)	2.20% (Single result)
Glacial Till (GT)	64(1)	Range = 93.80% - 110.50 % Average= 100.90 %	Range = -4.20 – 6.30% Average = 0.80%
Silty Clay (SC)	1	93.20% (Single result)	12.10% (Single Result)
Weathered Coarse Grained Rock (WCGR)	22(2)	Range = 92.70 – 106.40 % Average = 95.70%	Range = -3.20 – 7.3% Average = 3.60%
Granular Made Ground (GRMG)	12	Range = 93.50 – 98.50 % Average = 95.60%	Range = -0.40 – 4.30% Average = 2.40%
Fine Grained Rock Capping Layer (FGR)	62 (2)	Range = 92.40 – 106.30 % Average = 97.20 %	Range = -10.50 – 9.60% Average = 2.40%
Cohesive Made Ground(w/coal) (CMG)	24	Range = 95.80 – 108.10 % Average = 100.70 %	Range = -15.2 – 1.80% Average = -7.6%

Overall total of all materials (weighted average for quantity)*	**1291 (101)**	**Range = 91.20 – 111.50%** **Average = 98.25%**	**Range = -15.10 – 16.80%** **Average = 3.65%**

* Overall totals are a weighted average calculated based on the relative quantities of various material types placed, so that the average is representative of the bulk material placed.

The number of tests which indicated a non-compliant result is shown in brackets. In these instances the fill was in most cases subject to further compactive effort and retested. The results summarised above do not include these non-compliant test results in the range or average reported.

5.2.2 The NDG tests indicate general compliance with the specification, with exception of the deviations which are detailed in **Appendix F**.

5.2.3 In line with the approach agreed with the employer's engineer (and identified in TQ11), in all instances where NDG results indicated relative densities below 90% resulted in the material being subjected to further compaction and retested. Where NDG tests indicated relative density in the range 90% to 93% was not recorded as non-compliant, provided the running average of relative density was in excess of 95%, material was subjected to further compactive effort under the observation of the Geotechnical Engineer. In these cases the material was not subject to further testing as the result was considered to fall within the range of values that allowed the overall average relative density to be maintained within the acceptable limit of 95%. Where NDG results indicated relative density between 93-95% (i.e. marginal non-compliance) the result was not reported as non-compliant provided the running average was maintained at more than 95% and no rectification or re test was required.

5.2.4 From the NDG test results the air voids were calculated using the appropriate moisture content, dry density and particle density values (obtained from classification tests) as summarised in Table 5.1.

5.2.5 For most material types, the average air voids was below the target of 5% with only very occasional individual values above the individual target of 10%.

5.2.6 The average air voids for the FGR fill, at 6.00% marginally exceeds the target average of 5% with occasional individual values above the individual target of 10%. Assessment of the data (in conjunction with results of stiffness tests) suggest this is due to placement of this material at below optimum moisture content rather, than under compaction.

5.3 Results of Sand Replacement Tests (SRT)

5.3.1 Results of the SRTs are summarised in Table 5.2.

Table 5.2 – Summary of SRT Tests

Material	Number of tests	Relative Density %	Air Voids (%)
Fine Grained Rock	64(11)	Range = 91.70 – 104.90 Average = 98.50	Range = -5.50 – 17.50 Average = 8.70
Weathered Mudstone	26 (4)	Range = 93.00 – 104.60 Average = 98.20	Range = -1.60 – 15.30 Average= 7.10
Recycled Aggregate	6 (2)	Range = 96.40- 106.80 Average = 100.80	Range = -0.17-8.96 Average = 5.04
Cohesive Made Ground	23(3)	Range = 95.56 – 110 Average = 100.92	Range = -3.2 – 16.85 Average = 3.20

Material	Number of tests	Relative Density %	Air Voids (%)
Processed Demolition Rubble	0	-	-
Glacial Till	9(3)	Range = 92.27 – 109.62 Average = 101.8	Range = -0.02 – 10.22 Average = 4.17
Weathered Coarse Grained Rock	2	Range = 90.69 – 92.65 Average = 91.67	Range = 4.52 – 6.80 Average = 5.66
Granular Made Ground	1	99.5% (Single Result)	-2.6 (Single Result)
Sandstone Capping Layer	8	Range = 98.84 – 104.74 Average density = 98.82	Range = -1.36 – 8.90 Average = 3.83
Cohesive Made Ground with coal.	5	Range = 86.55 – 112.57 Average = 98.06	Range = -8.94 – 2.88 Average = -2.31
Overall total of all materials (weighted average for quantity)*	**144 (23)**	**Average = 99.01%**	**Average = 6.12%**

* Overall totals are a weighted average calculated based on the relative quantities of various material types placed, so that the average is representative of the bulk material placed.

The number of tests which indicated a non-compliant result is shown in brackets. In these instances the fill was in most cases subject to further compactive effort and retested. The results summarised above do not include these non-compliant test results in the range or average reported.

5.3.2 SRT's were difficult to execute in the coarse granular fill. As the 150mm deep holes are constructed by hand, it was extremely difficult to achieve the correct depth and shape without over or under excavation and reducing/increasing the dimensions. As such, the results of the tests are are likely to have been significantly altered and are considered unlikely to be representative.

5.3.3 The SRT test results indicate general compliance with the 95% relative density target with the exception of the weathered coarse grained rock, for which results indicate an average value of 91.67%. Results which did not comply with the specification are listed in **Appendix F.**

5.3.4 For the material types used as engineered fill, the SRT results indicate the average air voids generally exceeds the target of 5% for the granular fill but indicates less than 5% air voids in the cohesive material. Occasional values exceed the individual target result of 10% air voids for the majority of material types. Results which did not comply with the specification are listed in **Appendix F**.

5.3.5 A frequent number of SRT tests returned very low moisture contents in comparison with the classification tests and NDG tests on similar material. The low moisture content affected the calculated air voids result, resulting in values greater than calculated from the NDG test data. Low moisture content values recorded within the clay fills appeared to be unrealistic at times and not representative of the material placed. When undertaking SRT's, it was common in all material types to find cobbles within the diameter of the test hole. When determining the density and moisture content in the laboratory, the cobbles had a disproportionate effect on both values but mainly on the moisture content. It is considered that the SRT values are not entirely representative with regards to relative density or air voids due to the coarse nature of the fills placed, which is a recognised limitation to the use of SRTs to measure relative density and air voids of coarse fills.

5.4 Results of Plate Bearing Tests (PBT)

5.4.1 The results of the PBTs were utilised to obtain a measure of drained Stiffness (E') and undrained stiffness (E_u)using the Highways Agency Method and in accordance with BS1377: part 9 and using a relationship of drained to undrained stiffness of E' = 0.8Eu. These results are presented in **Appendix E** and summarised in **Table 5.3** below.

Table 5.3 – Summary of Test Results

Material	Number of tests	Undrained Stiffness (MPa)	Drained Stiffness (MPa)
Fine Grained Rock (FGR)	80(11)	Range: (14 – 62) Average = 29	Range: 11 – 50 Average = 23
Weathered Mudstone (WM)	30	Range: 16 – 50 Average = 28	Range: 12- 40 Average = 23
Recycled Aggregate (RA)	8(3)	Range: 17 - 30 Average = 24	Range: 13 – 24 Average = 19

Cohesive Made Ground (CMG)	10(1)	Range: 17 – 22 Average = 20	Range: 14 – 18 Average =16
Processed Demolition Rubble (PDR)	0		
Glacial Till (GT)	11(1)	Range 16 – 28 Average = 20	Range: 13 – 22 Average = 16
Weathered Coarse Grained Rock (WCGR)	6(1)	Range: 18 – 27 Average = 25	Range: 18 – 22 Average = 20
Granular Made Ground (GRMG)	0		
Fine Grained Rock Capping Layer (FGR)	5	Range: 15.00 - 85 Average = 51.00	Range12.00 – 67.80 Average = 41.00
Cohesive Made Ground w/coal (CMG)	1	15.50 (Single Result)	12.40 (Single Result)
Total	**151 (17)**	**Average stiffness value = 28.2**	**Average stiffness value = 22.6**

The number of tests which indicated a non-compliant result is shown in brackets. In these instances the fill was in most cases subject to further compactive effort and retested. The results summarised above do not include these non-compliant test results in the range or average reported.

5.4.2 The number of tests which indicated a non-compliant result is shown in brackets.

5.4.3 The majority of plate load tests confirmed acceptable stiffness criteria had been achieved with 134 of the 151 tests confirming acceptability. Several non-compliant results were recorded and fill materials at those locations were subject to rectification as outlined on **Table F-5** in **Appendix F**.

5.5 Results of California Bearing Ratio Tests (CBR)

5.5.1 Results of the in situ CBR tests on the fill placed as the 500mm capping layer across the site are summarised in Table 5.4. The results are included as **Appendix E**. Two different types of FGR (Siltstone and Sandstone) were used as capping.

Table 5.4 – Summary of CBR Tests

Material	Number of tests	Results (CBR)
Fine Grained Rock Capping (Siltstone)	3	18-45% (average = 36%)
Fine Grained Rock Capping (Sandstone)	33 (14)	20-83% (average = 35%)

5.5.2 In the initial stages of the enabling works, a series of tests were carried out to investigate whether the FGR (siltstone/sandstone) or weathered mudstone could achieve the 20% CBR target criteria. These tests (CBR 01 – CBR 14) were carried out on general fill using the plate load method. The range of

results were variable (2.7-72.7%) and did not indicate that a CBR of 20% could be reliably achieved using site won FGR (Siltstone) or mudstone.

5.5.3 As the Gateway Area was due to be completed and handed over by March 2013, a capping material had to be placed to achieve finished levels. The material which was used for this area comprised a sandy Siltstone present as a layer approximately 0.5m thick immediately above the Upper Metal Coal Seam. The three CBR tests carried out in this material (Ref. FGR CBR 15-17) achieved an average CBR value of 36% (18.6% – 44.9%) and was considered to be broadly acceptable. However, at MMs request this material was not considered suitable to be used as capping for the remainder of the site area due to its argillaceous nature and a more durable material was specified.

5.5.4 The remainder of the site – outside the Gateway Handover Area – was provided with a capping layer comprising silty sandstone crushed to a general 6F2 grading. Classification testing showed that occasional samples indicated a Class 1C grading and the largest particle size is to be marginally greater than 125mm. Thirty three CBR tests were carried out on the crushed sandstone; fourteen were below the required target value of 20%. Of these fourteen, thirteen of the tests were subject to further compaction and the retest achieved a value higher than 20%. One test was not subject to further testing as the failure was marginal – 19%.

5.6 Conclusion of Compliance Tests

5.6.1 The frequency of compliance tests was carried out in general accordance with the requirements of **Table 1/5 Appendix 1/5** of the Earthworks Specification.

5.6.2 Endeavours were made to ensure the testing was distributed evenly throughout the volumes of fill placed, although due to variation in material types used, weather conditions and the progress of the earthworks in a series of small areas, the proposed grid of testing was not always regular in terms of location or elevation.

5.6.3 The results of the compliance tests indicate that the relative density, undrained stiffness and drained stiffness of the fills placed generally complies with the requirements as set out in **Table 6.1 Appendix 6/1** of the Earthworks Specification (as amended by TQs). Locations where these requirements were not met are summarised in the Non-Conformity Register in **Appendix F**.

5.6.4 An average relative density of more than 95% was achieved for all material types (with the exception of the processed demolition rubble), with an overall average for all fills placed of 98 % (measures using NDT methods) or 99% measured using SRT methods.

5.6.5 Calculations of air voids (from NDTs) indicate average values below 5% for most material types with very occasional individual values in excess of 10%. The FGR fill recorded average air voids of 6%, marginally exceeding the 5% criteria and some individual results recorded air voids above 10%. Air voids calculated from the results of SRTs were generally higher than those calculated from NDG test data, with an average air voids for all materials placed of 6%. As discussed in Section 5.3, this is considered to be due to limitations of the SRT in soils dominated by coarse particles.

5.6.6 Rectification measures to reduce air voids in the FGR material were carried out, including the addition of water during compaction to increase moisture content and compactive effort. However, due to the coarse nature of this material, calculated air void values where consistently high, even where those fills had been compacted to effective refusal.

5.6.7 134 of the 151 PBTs confirmed the required stiffness criteria has been achieved for the engineered fill. Where tests did not confirm required stiffness had been achieved, additional rectification measures were carried out, comprising both removal and replacement of non-compliant fills or

additional compaction. Consequently, only one PBT indicates a marginal value below the required stiffness (L1 FGR PBT 1).

6 Mineshaft Investigation and Treatment

6.1.1 The base of all excavations, either for coal extraction or Made Ground turnover outwith the excavation, were inspected by the WSP Engineer and/or HCSL site foreman to visually assess for evidence of recorded or unrecorded mineshafts. Records of the areas inspected is provided in **Figure 5** in **Appendix B**. Areas not subject to excavation or Made Ground turnover, or where the surface of the natural strata was not exposed during the enabling works were not inspected (eg, site boundary stand-off zone, Corporation Street, main sewer stand-off and the western part of Site B).

6.1.2 The published records collated by MM identify ten recorded mine shafts within the site boundary, that are summarised on **Figure MMD-283831-C-DR-00-XX-7001 REV P5** in **Appendix B**. Details of the mine shafts encountered are outlined below and **Drawing DD204CA** showing the location of the mine shaft features encountered is presented in **Appendix K**. Records of the measures undertaken to treat the shafts is included in the reporting by Groundshire Ltd.

6.1.3 The following provides a summary of WSP observations related to the shafts encountered. A summary of shaft treatment, including location, elevation, foundation strata and size is provided in the shaft register in **Appendix B**. Standard shaft cap designs were prepared by WSP as shown on **Figure S2000 – S2002** in **Appendix B** but the choice of cap used on each shaft was determined by HCSL on the basis of the observed shaft diameter.

6.2 Recorded Mineshafts

6.2.1 *Shaft 1* was identified in June 2013 as a large reinforced concrete shaft cap at its recorded location. As the coal extraction excavation continued, the shaft was visible in the temporary high wall, extending below the base of the Metal Coal Seam. In November 2013, the mine shaft infill was consolidated by grout injection and a 6.4 x 6.4m shaft cap was constructed.

6.2.2 *Shaft 2* was identified in October 2013 at its recorded location. The shaft had previously been plugged with concrete at the level of the High Main Coal Seam. On removal of the concrete plug, sandstone bedrock was present with no evidence of the shaft continuing below this level. Therefore, no shaft treatment or mine shaft cap was undertaken.

6.2.3 *Shafts 3 and 4* were identified very close together in their previously recorded location within the early stages of excavation in cut 16 in November 2013. Both shafts were sandstone lined and extended beyond the base of the Metal coal seam. The infill of the shafts was consolidated by grout injection between 02 December 2013 and 12 December 2013. The two shaft caps, both 6.4m x 6.4m were installed side by side on 10 December 2013 and 12 December 2013.

6.2.4 *Shaft 5* was observed within the south of cut 11, close to its previously recorded location. The area was excavated on 04 July 2013 to a depth of approximately 0.5m below the base of the Metal seam and there was no evidence of the shaft continuing below this level. Therefore, no shaft treatment or mine shaft cap was undertaken.

6.2.5 *Shaft 6* was identified in August 2013 close to its previously recorded location, in the sandstone bedrock as the excavation in cut 13 extended below the base of the Made Ground. As the Metal coal seam was excavated, an area of soft, wet cohesive Made Ground was present. The material was excavated to a depth of approximately 0.5m and there was no evidence of the shaft continuing below this level. Therefore, no shaft treatment or mine shaft cap was undertaken.

6.2.6 *Shaft 7* was identified in September 2013 close to its previously recorded position when a reinforced concrete cap (understood to have been previously placed by Groundshire in 2008) was broken out

and removed. Upon reaching the base of the cut on 10 September 2013 it was clear that the shaft extended below the Metal coal seam as the material beneath was heavily disturbed. As the shaft had previously been drilled and grouted by Groundshire, no further treatment of the infill was undertaken(correspondence between Groundshire and HCSL). At the base of the cut, a shaft cap measuring 6.4m x 6.4m was installed.

6.2.7 *Shaft 8* was shown on the Coal Authority records to be within the Gateway Handover Area, just outwith the planned opencast excavation. The co-ordinates given by the Coal Authority were estimates. The Made Ground turnover within the suspected area began on 16 February 2013. During investigative works, a series of deep voids filled with Made Ground – some up to approximately 3.5m deep- were encountered within natural strata. The Made Ground within these localised areas was excavated until natural strata was proven. The deepest area of Made Ground backfill was approximately 4m bgl. It was uncertain whether the base was bedrock or possibly an obstruction within a shaft. Consequently the feature was drilled by Groundshire and rock was proven between 4.5-5.5m below original ground level. A shaft in this area has not been proven as part of these works. The 'known' mineshaft for *Shaft 8* identified on the HCSL drawing indicates the area that was investigated. However, an adjacent shaft identified in the base of the coal extraction has been considered to be *'shaft 8'*.

6.2.8 *Shaft 9* was not identified during the excavation works within the indicated location. It was noted that the co-ordinates of the shaft was an approximation based on a Coal Authority Report. It is possible that shaft 20 (see Section 6.3), located approximately 20m south east of the expected position of *Shaft 9*, represents this shaft.

6.2.9 *Shaft 10* was located within Site B but the exact co-ordinates of the shaft were unknown. After extensive investigative works to remove the Made Ground within a 20 x 20m area of the location, an area of wet, low strength clay was identified. After localised excavation to a depth of approximately 2m, it was initially thought this represented *Shaft 10*, approximately 5-10m north of its indicated location. The area was proof drilled on 18 February 2013 by Groundshire Ltd, which proved 5m of solid rock. As such, this feature is not considered to represent the shaft. The 'known' mineshaft for *Shaft 10* identified on the HCSL drawing indicates the area that was investigated.

6.3 Unrecorded Mineshafts

6.3.1 During observations of the base of excavation for coal extraction and Made Ground turnover, evidence of eleven additional suspected mineshafts was identified and is detailed below. The positions of these features are shown on **Drawing DD204CA** in **Appendix B**.

6.3.2 *Shaft 11* was observed in the base of Cut 1 as a 2.0m diameter brick lined circular feature and shallow excavation works showed the shaft continued below the base of the excavation. The shaft was drilled on 08 January 2013 and the shaft infill was consolidated by grout injection by Groundshire Ltd and provided with a reinforced concrete cap measuring 6.4m x 6.4m. It is possible that this unrecorded mine shaft is in fact the 'known' or 'recorded' mineshaft, *Shaft 8,* as shown on Coal Authority records and HCSL **Drawing DD204CA**.

6.3.3 *Shaft 12* was observed during excavation of Cut 1 as a brick lined rectangular feature 1.4 x 1.0m in plan. It was noted to bottom out at the base of the excavation in the Metal Seam and drilling of this feature from the base of the cut on 19 December 2012 proved solid rock to 5.0m below the base of the excavation. Therefore, no shaft treatment or mine shaft cap was undertaken. It is possible that *Shaft 12* is in fact *Shaft 8* as shown on the Coal Authority records.

6.3.4 *Shaft 13* was identified in the temporary high wall in between Cut 4 and 12 in January 2013. As it was located within the high wall, it was excavated on 09 August 2013 when cut 12 was excavated.

Disturbed ground extended slightly deeper than the floor of the Metal Coal seam in a south easterly direction. The Made Ground was removed until natural rock stratum was proved below the shaft. There was no evidence of the shaft continuing below this level. Therefore, no shaft treatment or mine shaft cap was undertaken.

6.3.5 *Shaft 14* was observed in the high wall of Cut 5, adjacent to Corporation Street. Due to time constraints, the shaft was surveyed and then temporarily backfilled until Groundshire could mobilise specialist plant onto the site to treat the shaft. The shaft infill was consolidated by grout injection on 12 and 13 February 2013. The location of the shaft within the high wall did not allow for a mine shaft cap to be placed as the high wall could not be cut further back due to the risk of undermining the highway. Hence, Shaft 14 was provided with a concrete 'plug' placed on 02 February 2013 in accordance with Coal Authority agreement (Leigh Sharpe correspondence in **Appendix I**) and as shown in **Figure 5001** in **Appendix B**.

6.3.6 *Shaft 15* was observed in Cut 6 during February 2013 in the shallow stages of the excavation. During subsequent deep excavation to remove coal, it was apparent that the shaft terminated at the High Main Coal seam and did not penetrate any deeper. Therefore, no shaft treatment or mine shaft cap was undertaken.

6.3.7 *Shaft 16* was identified close to the northern boundary of Site B. The shaft was approximately 2m in diameter and contained a length of timber, approximately 3m long. The Made Ground was excavated on 03 June 2012 to a depth of approximately 4m bgl where natural stratum was encountered. The shaft terminated in Mudstone and no seam of coal was penetrated. The shaft was considered likely to have been a well, possibly associated with the former brewery. The hole was subsequently backfilled in layers and no further treatment was undertaken.

6.3.8 *Shaft 17* was identified in Cut 18 on approximately 14 June 2013 within the sandstone bedrock as the excavation progressed. When the base of the Metal Seam was reached, excavation of the shaft revealed a stiff, light grey Mudstone. From approximately 1m below the seam level no evidence of the shaft continuing was noted, therefore, no mine shaft treatment or shaft cap was undertaken.

6.3.9 *Shaft 18* was identified in Cut 10 on 05 July 2013 during the excavation of the Upper Metal Coal Seam. The area was excavated below the Metal Seam and identified natural rock strata on 08 July 2013. There was no evidence of this shaft continuing below the level of the Metal Seam. Therefore, no mine shaft treatment or shaft cap was undertaken.

6.3.10 *Shaft 19* was identified in Cut 11 on July 2013 during the excavation within the Upper Metal Coal Seam. The area was excavated on 26 July 2013 below the Metal Coal Seam and identified a depth of approximately 2m of soft cohesive Made Ground, below which natural rock strata was encountered. There was no evidence of this shaft continuing below the level of the Metal Seam and the void was backfilled in layers. Therefore, no mine shaft treatment or shaft cap was undertaken.

6.3.11 *Shaft 20* was identified on 20 September 2013 when carrying out the Made Ground turnover to the east of Cut 14. An area of soft Made Ground was excavated to a depth of approximately 3m below excavation level but did not reach natural strata. The shaft was drilled by Groundshire on 02 October 2013 to a depth of 26m bgl (5m below the base of natural) and consolidated by grout injection. A 6.4m x 6.4m shaft cap was placed on 10 October 2013.

6.3.12 *Shaft 21* was identified in temporary high wall in the north east of the site in Cut 15. As the excavation continued above, it was evident that the shaft bottomed out in the High Main coal seam as a roadway was visible leading into the seam. Below the base of the shaft, solid rock was proven by excavation. There was no evidence of the shaft continuing below the level of the Metal Seam. Therefore, no mine shaft treatment or shaft cap was undertaken.

7 High Wall Records

7.1.1 In accordance with the ERs and to satisfy the requirements of the Geotechnical Design Report, a record of the strata within the permanent high wall faces was maintained. This is presented as a series of scanline records at frequent intervals around the high wall presented in **Appendix J**. In addition, a photograph showing the strata at each location is also included in **Drawings Scanline 01-12** and annotated accordingly. **Figure 6** in **Appendix J** indicates locations where scan line records were taken.

7.1.2 Week day monitoring of the temporary and permanent high wall was undertaken by the geotechnical engineer to assess their stability. In addition, safety inspections were also undertaken by HCSL personnel. Generally the massive bedded sandstone remained stable throughout the excavation. On three separate occasions, localised instability was noted within the high wall and remedial actions were carried out. They were as follows:

- On 29 June 2013 a tension crack was noted at the crest of the temporary high wall between cuts 5 and 6. Immediate action was taken to excavate the Made Ground from the top of the high wall and a rock bench remained in situ at the base of the wall. Once excavation works were complete in the base of the hole, the clay was side casted from the high wall and backfilling commenced immediately to provide weight at the toe of the high wall
- On 22 April 2013, works were brought forward to demolish the retaining wall alongside Cut 9 as cracking was noted in the block faces of the permanent high wall. The retaining wall was reduced to ground level over an eight hour period and excavation works within the adjacent cut continued. Once the coal as removed from the opencast, material was placed, compacted and the levels were backfilled to the crest of the retaining wall to tie in with finished site levels;
- On 29 November 2013 a localised area within the permanent high wall of Cut 16 and 17 showed signs of instability, with cobbles beginning to fall into the bench cut below. Initially, the disturbed and unstable ground was presumed to be an old bell pit due to its shape. By 10 December 2013, small tension cracks were identified at the crest of the high wall. Backfilling works were prioritised below this area of the high wall, the remaining cut face was cut back to an appropriate 1h:2v angle and no further movement was observed.

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Appendices

Appendix A – Notes on Limitations

Appendix B- Drawings & Photographs

Appendix C - Classification Tests

Appendix C.1 Fine Grained Rock

Appendix C.2 Weathered Mudstone

Appendix C.3 Recycled Aggregate

Appendix C.4 Cohesive Made Ground

Appendix C.5 Cohesive Made Ground with Coal

Appendix C.6 Processed Demolition Rubble

Appendix C.7 Glacial Till

Appendix C.8 Weathered Coarse Grained Rock

Appendix C.9 Granular Made Ground

Appendix C.10 Fine Grained Rock (Capping material)

Appendix D - Compaction Trials

Appendix E - Compliance Tests

Appendix F- Non Conformity Register

Table F-1 – Summary of NDG Non Conformities Relating to Relative Density

Date	Test ID	Deviation	Rectification carried out	Retest value
16.01.13	FGR NDG 35	86.9% relative compaction	Applied two more passes and retested (FGR NDG 36)	94.03%
19.02.13	WM NDG 143	89.8% relative compaction	Layer removed to achieve final finished levels	-
11.03.13	FGR NDG 207	85.8% relative compaction	Layer removed, rerolled with eight passes and retested (FGR NDG 208)	93.14%
12.03.13	WM NDG 211	86.1% relative compaction	Applied two more passes and retested (WM NDG 214)	97.32%
27.03.13	WM NDG 253	88.6% relative compaction	Applied two more passes and retested (WM NDG 254)	93.43%
11.04.13	WM NDG 316	87.6% relative compaction	Applied two more passes and retested (WM NDG 317)	97.81%
15.04.13	FGR NDG 332	89.7% relative compaction	Bladed off heavily tracked rock and fresh layer of sandstone was added, compacted and retested (FGR NDG 333)	98.53%
22.05.13	WCGR NDG 448	89.7% relative compaction	Material was re-tracked, and six more passes applied and retested (WCGR NDG 449)	96.57%
18.06.13	WM NDG 516	87.8% relative compaction	Applied two more passes and retested (WM NDG 517)	93.17%
26.06.13	FGR NDG 542	87.25% relative compaction	Initially failed due to high air voids (FGR NDG 541) so material was sprayed, rerolled and retested (FGR NDG 542). Retest failed but due to relative density. Material re-tracked and rerolled and failed air voids once again. Additional compaction was undertaken and retested (FGR NDG 544)	95.10%
26.06.13	WM NDG 545	89.3% relative compaction	Applied two more passes and retested (WM NDG 546)	93.66%
31.10.13	WCGR NDG 994	89.7% relative compaction	Retest carried out in similar area (WCGR NDG 997). Due to consistently low results, further 4.5kg compaction testing was carried out on this material to investigate running maximum dry density average	94.61%

Table F-2 –Summary of NDG Non Conformities Relating to Air Voids

Date	Test ID	Deviation	Rectification carried out	Retest Value
15.01.13	FGR NDG 24	10.2% calculated air voids	None	
16.01.13	FGR NDG 31	13.4% calculated air voids	None	
16.01.13	FGR NDG 32	11.9% calculated air voids	None	
17.01.13	FGR NDG 44	14.1% calculated air voids	Two more passes	
17.01.13	FGR NDG 45	16.2% calculated air voids	None	
18.01.13	FGR NDG 50	10.3% calculated air voids	None	

Date	Test ID	Deviation	Rectification carried out	Retest Value
25.01.13	FGR NDG 69	12.2% calculated air voids	None	
12.02.13	FGR NDG 105	14.0% calculated air voids	None	
13.02.13	FGR NDG 111	12.4% calculated air voids	None	
14.03.13	FGR NDG 115	11.3% calculated air voids	None	
15.03.13	FGR NDG 122	11.4% calculated air voids	None	
18.02.13	FGR NDG 135	10.6% calculated air voids	None	
19.02.13	RA NDG 140	10.9% calculated air voids	None	
26.02.13	FGR NDG 155	11.1% calculated air voids	None	
26.02.13	FGR NDG 156	10.7% calculated air voids	None	
26.02.13	FGR NDG 157	12.0% calculated air voids	None	
27.02.13	FGR NDG 159	11.1% calculated air voids	None	
28.02.13	FGR NDG 166	11.0% calculated air voids	None	
04.03.13	FGR NDG 170	14.5% calculated air voids	None	
06.03.13	FGR NDG 184	11.1% calculated air voids	None	
06.03.13	FGR NDG 186	11.2% calculated air voids	None	
12.03.13	FGR NDG 208	10.6% calculated air voids	None	
12.03.13	CMG NDG 209	5.3% calculated air voids	None	
25.03.13	CMG NDG 240	5.3% calculated air voids	None	
25.03.13	FGR NDG 243	16.8% calculated air voids	None	
26.03.13	CMG NDG 249	5.0% calculated air voids	None	
28.03.13	FGR NDG 262	13.7% calculated air voids	None	
28.03.13	FGR NDG 263	11.4% calculated air voids	None	
28.03.13	FGR NDG 264	14.0% calculated air voids	None	

Date	Test ID	Deviation	Rectification carried out	Retest Value
02.04.13	FGR NDG 270	10.90% calculated air voids	None	
02.04.13	FGR NDG 274	12.3% calculated air voids	None	
03.04.13	FGR NDG 281	15.4% calculated air voids	None	
03.04.13	FGR NDG 284	12.3% calculated air voids	None	
04.04.13	FGR NDG 287	13.6% calculated air voids	None	
04.04.13	FGR NDG 289	12.4% calculated air voids	None	
04.04.13	FGR NDG 290	10.8% calculated air voids	None	
08.04.13	FGR NDG 293	11.6% calculated air voids	None	
10.04.13	FGR NDG 300	10.0% calculated air voids	None	
15.04.13	FGR NDG 333	12.2% calculated air voids	None	
15.04.13	FGR NDG 337	15.8% calculated air voids	None	
17.04.13	CMG NDG 349	10.2% calculated air voids	None	
17.04.13	FGR NDG 350	12.4% calculated air voids	None	
17.04.13	FGR NDG 351	12.6% calculated air voids	None	
22.04.13	FGR NDG 365	10.2% calculated air voids	None	
23.04.13	CMG NDG 373	7.1% calculated air voids	None	
24.04.13	FGR NDG 380	11.3% calculated air voids	None	
26.04.13	FGR NDG 384	10.3% calculated air voids	Additional compaction applied and retested (FGR NDG 386)	7.71%
29.04.13	FGR NDG 389	15.4% calculated air voids	Additional compaction applied and retested (FGR NDG 390)	8.17%
02.05.13	FGR NDG 397	11.7% calculated air voids	Water applied, rerolled and retested (FGR NDG 398)	5.94%
03.05.13	FGR NDG 403	12.2% calculated air voids	Water applied, re-tracked, rolled and retested (FGR NDG 404)	1.74%
13.05.13	FGR NDG 418	10.8% calculated air voids	Re-tracked, applied two more passes and retested (FGR NDG 421)	5.94%
14.05.13	CMG NDG 424	9.9% calculated air voids	Additional compaction applied	

Date	Test ID	Deviation	Rectification carried out	Retest Value
23.05.13	FGR NDG 455	13.8% calculated air voids	Additional compaction applied	
06.06.13	FGR NDG 474	13.9% calculated air voids	Tests are part of a compaction trial	
06.06.13	FGR NDG 475(1)	10.5% calculated air voids		
06.06.13	FGR NDG 475(2)	13.5% calculated air voids		
06.06.13	FGR NDG 475(3)	12.4% calculated air voids		
07.06.13	RA NDG 479	12.1% calculated air voids	Applied two more passes and retested (RA NDG 480)	9.61%
10.06.13	FGR NDG 490	12.2% calculated air voids	Additional compaction applied	
10.06.13	CMG NDG 491	5.8% calculated air voids	Additional compaction applied	
12.06.13	CMG NDG 497	7.1% calculated air voids	Additional compaction applied	
12.06.13	FGR NDG 498	12.05% calculated air voids	Additional compaction applied	
12.06.13	RA NDG 499	11.4% calculated air voids	Applied more passes and retested (RA NDG 503)	8.1%
12.06.13	FGR NDG 501	10.2% calculated air voids	Additional compaction applied	
18.06.13	WM NDG 514	11.6% calculated air voids	Additional compaction applied	
18.06.13	FGR NDG 515	12.5% calculated air voids	Water applied, rerolled and retested (FGR NDG 518)	4.9%
19.06.13	FGR NDG 521	11.1% calculated air voids	Additional compaction applied	
20.06.13	RA NDG 526	12.4% calculated air voids	Applied more passes and retested (RA NDG 529)	-0.06%
24.06.13	FGR NDG 530	11.1% calculated air voids	Water applied, rerolled and retested (FGR NDG 536)	8.8%
25.06.13	FGR NDG 533	13.5% calculated air voids	Water applied, rerolled and retested (FGR NDG 534)	6.4%
25.06.13	RA NDG 538	12.1% calculated air voids	Applied two more passes and retested (RA NDG 539)	0.5%
26.06.13	FGR NDG 541	11.8% calculated air voids	After a combination of remediation methods, a retest was carried out which achieved target parameters (FGR NDG 544)	
26.06.13	FGR NDG 543	11.8% air voids		5.5%
01.07.13	FGR	11.2% calculated	Applied two more passes and retested (FGR NDG 559)	9.3%

Date	Test ID	Deviation	Rectification carried out	Retest Value
	NDG 554	air voids		
03.07.13	FGR NDG 568	11.9% calculated air voids	Additional compaction applied	
08.07.13	CMG NDG 574	7.4% calculated air voids	Applied two more passes and retested (CMG NDG 575)	5.5%
08.07.14	CMG NDG 575	5.6% calculated air voids	Applied additional compaction	
08.07.13	CMG NDG 580	5.6% calculated air voids	Applied two more passes and retested (CMG NDG 581)	3.8%
30.07.13	FGR NDG 674	10.8% calculated air voids	Applied two more passes and retested (FGR NDG 676)	6.5%
31.07.13	FGR NDG 684	10.1% calculated air voids	Applied two more passes and retested (FGR NDG 685)	8.65%
01.08.13	FGR NDG 689	11.8% calculated air voids	Water applied, rerolled and retested (FGR NDG 690)	3.5%
12.08.13	FGR NDG 736	10.9% calculated air voids	Water applied, rerolled and retested (FGR NDG 741)	3.5%
21.08.13	FGR NDG 780	15.8% calculated air voids	Area excavated, rerolled and retested (FGR NDG 781)	4.7%
17.09.13	FGR NDG 838	10.0% calculated air voids	Marginal – no action required. A test in a similar location was carried out (FGR NDG 843)	6.9%
17.09.13	FGR NDG 841	10.1% calculated air voids	Marginal - no action required. A test in a similar location was carried out (FGR NDG 844)	5.45%
20.09.13	FGR NDG 862	11.9% calculated air voids	Applied two more passes and retested (FGR NDG 863)	7.0%
24.09.13	FGR NDG 876	11.9% calculated air voids	Area re-tracked, applied two more passes and retested (FGR NDG 880)	7.4%
27.09.13	CMG NDG 898	5.3% calculated air voids	Applied two more passes and retested (CMG NDG 899)	2.7%
01.10.13	FGR NDG 914	11.9% calculated air voids	Applied two more passes and retested (FGR NDG 916)	8.1%
03.10.13	FGR NDG 928	13.2% calculated air voids	Area re-tracked, applied two more passes and retested (FGR NDG 929)	6.1%
11.10.13	CMG NDG 948	5.2% calculated air voids	Applied two more passes and retested (CMG NDG 949)	0%
04.11.13	FGR NDG 1003	10.5% calculated air voids	Applied more passes and retested (FGR NDG 1004)	3.4%
07.11.14	FGR NDG 1027	11.4% calculated air voids	Applied more passes and retested (FGR NDG 1028)	7.4%
15.11.13	FGR NDG 1052	10.3% calculated air voids	Applied more passes and retested (FGR NDG 1053)	9.1%
29.11.13	FGR NDG 1086	10.4% calculated air voids	Applied two more passes and retested (FGR NDG 1088)	9.4%

Date	Test ID	Deviation	Rectification carried out	Retest Value
12.12.13	FGR NDG 1139	10.1% calculated air voids	Applied more passes and retested (FGR NDG 1143)	6.75%
12.12.13	FGR NDG 1140	10.8% calculated air voids	Applied more passes and retested (FGR NDG 1143)	6.75%

Table F-3 – Summary of SRT Non Conformities in Relation to Relative Density

Date	Test ID	Deviation	Rectification carried out	Retest Value
11.01.13	RA SRT 2	88.2% relative compaction	Wood fragment was logged within test hole – re test carried out (RA SRT 4)	96.4%
06.02.13	WM SRT 11	70.2% relative compaction	Layer removed when shaft 14 was treated	-
11.03.13	FGR SRT 19	Compaction value of approximately 150%.	Testing result void.	-
02.04.13	FGR SRT 27	84.3% relative compaction	Material removed to form part of backfill in adjacent cut	-
03.04.13	FGR SRT 28	88.7% relative compaction	Applied two more passes and retested in a similar area (FGR SRT 29)	94.1%
02.07.13	WM SRT 55	83.4% relative compaction	Apparent error with the calculated moisture content (23%). Moisture Contents during classification and compliance testing averaged 10%	-
05.07.13	RA SRT 56	86.4% relative compaction	Additional compaction applied - a retest carried out on similar material elsewhere (RA SRT 57)	103.3%
30.08.13	CMG SRT 74	86.5% relative compaction	High content of coal within the SRT is likely to have affected the density reading	
04.02.14	FGR SRT 134	77.5% relative compaction	Additional compaction applied and retested (FGR SRT 135)	90.7%
07.02.14	FGR SRT 135	90.7% relative compaction	Additional compaction applied and retested after period of wet weather (FGR SRT 136)	102.5%

Table F-4 – Summary of SRT Non Conformities in Relation to Air Voids

Date	Test ID	Deviation	Rectification carried out	Retest Value
15.01.13	FGR SRT 3	10.4% calculated air voids	None	
23.01.13	FGR SRT 5	10.1% calculated air voids	None	
05.02.13	FGR SRT 10	10.9% calculated air voids	None	

Date	Test ID	Deviation	Rectification carried out	Retest Value
18.02.13	CMG SRT 13	5.1% calculated air voids	None	
18.02.13	FGR SRT 14	15.6% calculated air voids	None	
26.02.13	FGR SRT 16	13.6% calculated air voids	None	
04.03.13	WM SRT 18	14% calculated air voids	None	
15.03.13	WM SRT 22	15.3% calculated air voids	None	
19.03.13	FGR SRT 23	13.9% calculated air voids	None	
25.03.13	FGR SRT 24	14.9% calculated air voids	None	
04.04.13	FGR SRT 29	17.5% calculated air voids	None	
16.04.13	WM SRT 34	11.5% calculated air voids	None	
26.04.13	FGR SRT 38	10.2% calculated air voids	Marginal failure – no action required	
10.05.13	FGR SRT 41	13.2% calculated air voids	Additional compaction applied	
22.05.13	WM SRT 45	12.5% calculated air voids	Additional compaction applied	
07.06.13	CMG SRT 48	16.9% calculated air voids	Additional compaction applied	
12.06.13	FGR SRT 49	14.5% calculated air voids	Additional compaction applied	
14.06.13	GT SRT 50	10.2% calculated air voids	Additional compaction applied	
26.06.13	FGR SRT 54	11.7% calculated air voids	Additional compaction applied	
11.07.13	FGR SRT 59	12.7% calculated air voids	Additional compaction applied	

Date	Test ID	Deviation	Rectification carried out	Retest Value
11.07.13	FGR SRT 60	14.1% calculated air voids	Additional compaction applied	
16.07.13	FGR SRT 62	11.5% calculated air voids	Additional compaction applied	
18.07.13	FGR SRT 63	11.5% calculated air voids	Additional compaction applied	
14.08.13	WM SRT 70	10.1% calculated air voids	Marginal failure. A retest was carried out (WM SRT 71) but a spurious moisture content was recorded in this test	
01.10.13	FGR SRT 86	10.5% calculated air voids	Area of failed test re graded and additional compaction applied. Retest was carried out (FGR SRT 88)	7.9%
11.10.13	FGR SRT 90	14.2% calculated air voids	Layer was overfilled and re test had to be carried out on the same material in overlying layer (FGR SRT 96)	8.7%
11.10.13	FGR SRT 91	14.9% calculated air voids	Layer was overfilled and re test had to be carried out on the same material in overlying layer (FGR SRT 96)	8.7%
06.11.13	WM SRT 102	10.8% calculated air voids	Additional compaction applied and a plate load test was carried out on the same layer confirming acceptable stiffness parameters (WM PBT 116)	
06.11.13	CMG SRT 103	8.8% calculated air voids	High cobble content in the test hole likely to result in unrepresentative moisture content result. A retest was carried out on same material at a different location (CMG SRT 104)	3.6%
19.11.13	GT SRT 108	9.2% calculated air voids	High cobble content in the test hole likely to result in unrepresentative moisture content result. A retest was carried out on same material at a different location (GT SRT 109)	-0.02%
03.12.13	FGR SRT 113	10.5% calculated air voids	A plate load was carried out on the same material in a similar location (FGR PBT 126)	
11.12.13	CMG SRT 118	7.3% calculated air voids	Re-calculation using most recent particle density values gives <5% air voids	
13.12.13	GT SRT 119	6.2% calculated air voids	Once non-conforming result was received, a retest was scheduled but the layer was below subsequent compaction layers and no more Glacial Till was used for the remainder of the works	
16.12.13	CMG SRT 121	6.3% calculated air voids	Re-calculation using subsequent revised particle density values gives <5% air voids	
17.12.13	FGR SRT 122	12.3% calculated air voids	Additional compaction applied and retested (FGR SRT 124)	6.4%
10.01.13	FGR SRT 128	13.9% calculated air voids	Large cobble noted in test hole. Material was retested (FGR SRT 129)	9.45%

Table F-5 – Summary of PBT Non Conformities in relation to Undrained Stiffness

Date	Test ID	Deviation	Rectification carried out	Retest Value
13.12.13	L1 FGR PBT 1	14.2MPa undrained stiffness	Marginal – None required	
09.01.13	RA PBT 3	10.2MPa undrained stiffness	Testing carried out after a period of wet weather – wet layer bladed off and future PBT testing was not carried out immediately after rainfall.	
30.01.13	RA PBT 13	13.5MPa undrained stiffness	Retest carried out after applying 2 more passes (RA PBT 14)	18.77MPa
22.02.13	RA PBT 21	12.9MPa undrained stiffness	Material re-tracked, rerolled and retested (RA PBT 22)	19.99MPa
18.03.13	FGR PBT 30	10.5Mpa undrained stiffness	Test disturbed due to adjacent compaction works. Another test was carried out once the working area was expanded (FGR PBT 31)	15.25MPa
25.03.13	FGR PBT 32	12.4MPa undrained stiffness	Area subject to localised material removal and compaction applied once levels re graded.	
16.05.13	FGR PBT 48	8.5MPa undrained stiffness	Tested after heavy rain. Layer removed and test carried out on exposed fill. Retest complete (FGR PBT 49)	16.16MPa
01.10.13	GT PBT 102	9.8MPa undrained stiffness	Additional compaction applied and retested (GT PBT 103)	15.68MPa
05.11.13	WCGR PBT 113	9.2MPa undrained stiffness	Layer removed and new material was placed and retested (WM PBT 114)	25.4MPa
28.11.13	CMG PBT 122	9.4MPa undrained stiffness	Material removed and FGR capping layer placed over (Re test FGR PBT 123)	11.6MPa
28.11.13	FGR PBT 123	11.6MPa undrained stiffness	Mixture of sandstone and clay removed. Two thin layers of mudstone placed and retested (WM PBT 124)	47.9MPa
12.12.13	FGR PBT 129	13.3MPa undrained stiffness	Material removed and replaced and retested (FGR PBT 130)	17.6MPa
17.12.13	FGR PBT 132	10.3MPa undrained stiffness	Layer partially removed – additional rock fill placed (Retest PBT 133)	17.06MPa
09.01.13	FGR PBT 137	13.3MPa undrained stiffness	Two additional passes and a re test carried out (FGR PBT 138)	14.9MPa
09.01.13	FGR PBT 138	14.9MPa undrained stiffness	Material partially removed and sandstone placed. Re tests were carried out the next day (FGR PBT 139)	17.4MPa
13.01.13	FGR PBT 142	12.0MPa undrained stiffness	Material partially removed, rerolled and a layer of rock fill was placed. A retest was carried out (FGR PBT 143).	17.2MPa

Appendix G - Mineshafts

Appendix H -TQ responses

Appendix I - Correspondance

Appendix J - High Wall Logging

WSP UK Limited
Weymouth House
Hampshire Court
Newcastle Business Park
Newcastle Upon Tyne
NE4 7YG
Tel: +44 11 3395 6200
Fax: +44 113 395 6201
www.wspgroup.co.uk