Kilnwood Vale Phase 2.4E East B

Interim Factual Verification Report Covering Linden Homes Parcel 2F

December 2019

For

Crest Strategic Projects



Remediation of Contaminated Land & Water

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Specialist Environmental Contracting

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Appendix B – Contract Documents to include Project Specification and RFI's
Kilnwood Vale Phase 2.4-2.6 Earthworks Specification, April 2019;
Phase 2.4: Geotechnical Design Report for Earthworks Development Platform', Campbell Reith, Reference MLead-11950-270617-Phase 2.4 GDR F1.doc, June 2017;
Phase 2.4 Environmental Review and Remedial Strategy, CampbellReith, Ref. APPsmb11950-12052017-Rem_Strategy-ph2.4-F1, June 2017;
Materials Management Plan MMP Kilnwood Vale Phase 2.4-2.6
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Appendix C – Compaction Trial Report
DTR16525 Kilnwood Vale Phase 2.2b-2.6 – 2C Compaction Trial Report 2017

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Appendix H – Chemical and Forensic TOC Results

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Optimum Moisture Content / Maximum Dry Density (OMC / MDD) test certificates
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Indicative Phase Boundary Plan
As Built Plan Drawing
Cross section drawings
Non-Compliance Drawings

Appendix N – Installation Backfill Data

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Backfill Inspection Test Plans (ITP) sheets
Backfill Daily Layer Plans
Backfill ITP Tracker

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1. Background Information

1.1 Introduction and Objectives

Dunton Environmental Ltd (DEL) was appointed by Crest Strategic Projects (CSP) in January 2017 to undertake cut & fill activity at the former inert Holmbush Farm Landfill for the Kilnwood Vale Phases 2.2b – 2.6a project. Phase 2.4E East B which forms part of the Linden Homes Development Parcel 2F along with the contractual work boundaries is indicated on drawing 11950-SK107-P9 provided in **Appendix A**.

This report is an interim with respect to 2.4E East B as a whole with an update to this report to follow for the outstanding work. This report does however contain full information relating to the Linden Homes development parcel 2F located within Phase 2.4E East B.

Engineered fill, test certificates and daily layer plans etc. associated with Phase 2.4H that extend into 2.4E East B and the Linden Holmes development parcel 2F are not included in this report but are included in the previously issued 2.4H Verification report (DTR16525 Phase 2.4H Kilnwood Vale_Rev5 - December 2018) and 2.4H Snagging Letter (November 2019).

Engineered fill, test certificates and daily layer plans etc. associated with Phase 2.4E West A and 2.6B that extend into 2.4E East B shall be included as part of this report.

Works relating to phase 2.4E East B outstanding at the time of the issue of this report are listed as snagging items in Section 7 and indicated on drawing 16525-318 in **Appendix M**.

The objective of the work was to provide a re-graded earthworks platform for subsequent residential development with associated infrastructure.

The principle parties involved in the works were:

- Crest Nicholson Operations Limited – Employer
- Allen Dadswell Construction Consultants – Engineer to the Contract
- Dunton Environmental Limited – Contractor
- CampbellReith – Designer / Design Engineer and Engineers Representative (ER)

The earthworks were observed by a full time Engineers Representative (ER), provided by CampbellReith, with delegated duties from the Engineer to the Contract. The ER was present to observe works for general compliance with the specification / method statements; audit the implementation of in-situ field testing / sampling; and visually inspect layer formations, loose lift layers, proposed fill and completed layers.

The Phase 2.4E East B design requirements were principally contained in the following documents:

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- Kilnwood Vale Phase 2.4-2.6 Earthworks Specification, Rev E, April 2019
- Phase 2.4: Geotechnical Design Report for Earthworks Development Platform', Campbell Reith, Reference MLead-11950-270617-Phase 2.4 GDR F1.doc, June 2017;
- Phase 2.4 Environmental Review and Remedial Strategy, CampbellReith, Ref. APPsmb11950-12052017-Rem_Strategy-ph2.4-F1, June 2017

The above documents are included within **Appendix B.**

Campbell Reith developed the Earthworks Specification (April 2019, Rev. E) which sets out the requirements for the entire Phase 2.4 works. Phase 2.4E East B works have been undertaken in line with the specification Phase 2.4 Geotechnical Design Report for Earthworks Development Platform, and Construction Environmental Management Plan, CEMP (The CEMP is included in **Appendix F)**.

Thirty nine Engineers Variations (EVs) have been issued relating to updates to CampbellReith's earthworks drawings and specifications. Requests for Information (RFI's) were issued from DEL generally in order to clarify aspects of CR's specification. Copies of the EVs and RFI's are provided within **Appendix B**.

The Earthworks Specification is based upon Volume 1, Specification for Highway Works with the following particular end product requirements;

- Placement of compacted material to achieve >95% Maximum Dry Density (MDD), with a corresponding presence of <10% air voids ratio along with >50kPa shear strength;
- In-situ CBR on each of the top 2 layers (compacted as 0.50m) to be >3%;
- Plate Load derived CBR on the final formation to be >3%,
- All permanent engineered fill to achieve a maximum permeability of 10^{-7}m/s

1.2 Report Format

The report, in general follows the requirements described within the CampbellReith, Kilnwood Vale Phase 2.4-2.6 Earthworks Specification April 2019 Rev E (Appendix 6/3, Section 22), and contains the following information relating to works undertaken by DEL:

- General description of the earthworks excavation, placement and compaction methodology and plant used;
- Quantities of excavated and re-used materials, treated and disposed materials;
- Details of remediation (if any) and treatment, including quantities;
- The extent of the excavation formation;
- Detailed weather conditions;

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- Formation treatment including ground improvement and treatment of soft areas, or contamination;
- Data relating to the relevant compaction trials and the compaction trial reports for the materials used – Made Ground (Class 2 materials).
- Application of acceptability criteria and summary of the control test results for placed material within the Phase;
- A copy of all test results including grid location plan and level;
- Actions taken in relation to each specific earthworks material;
- Drawings showing the location of each specific earthworks material placed during earthworks operation on a layer by layer basis and the location of the trial areas and control tests;
- An electronic copy of all the test results and monitoring associated with the earthworks operations;
- Environmental monitoring results;
- Surcharge settlement monitoring procedures and records (with RSG data)
- Contamination relevant records; and,
- Copy of all relevant on-site compaction and laboratory test results.

This report comprises a comprehensive factual record of the field works and data including in-situ geotechnical testing, environmental monitoring (dust, noise, and odour), post earthworks gas monitoring (drum tests, borehole monitoring, surface emissions) and laboratory geochemical, geotechnical and contamination results. Also included are record of surcharge monitoring through the measurement of rod settlement gauges (RSGs), gas boreholes and piezometers. Work outstanding described below will be included in a later iteration of this report.

1.3 Scope of Works

A summary of the works undertaken is provided below:

- Undertake compaction trials;
- Install suitable temporary control measures to manage water;
- Strip vegetation and remove from works area;
- Excavate and stockpile topsoil for re-use by others;
- Excavate to the earthworks levels and transport soils to stockpiles or fill;
- Carry out surface emissions survey and validation trial pitting;
- Install surcharge monitoring Rod Settlement Gauges and Piezometers;
- Replace fill to revised design levels;
- Place Class 2 (landfill) material as Engineered fill;
- Undertake processing of fill materials at the point of placement
- Undertake geotechnical and contamination soil testing;
- Trim and form finished plateaus ready for follow on works by others (+50/-50mm) of the Final Formation Levels;

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- Place surcharge loading and monitor surcharge settlement;
- Complete environmental [noise, dust, odour, surface water] monitoring during works in accordance with the CEMP monitoring locations;
- Post earthworks gas monitoring;
- Gas monitoring exploratory holes;
- Infiltration soakaway tests;
- Decommission boreholes;
- Excavate and remove RSGs and associated temporary works;
- Re-engineer voids created through the removal of the RSGs and backfill with engineered fill;
- Re-engineer final formation level after trimming;
  Undertake geotechnical and chemical soil testing to demonstrate re-engineered materials have been re-instated and comply with the specification;
- Remove surcharge, predominantly in adjacent phases;
- Heave monitoring;
- Excavate and remove remaining RSGs and associated temporary works;
- Re-engineer voids created through the removal of the RSGs and backfill with engineered fill;
- Re-engineer final formation level after trimming;
- Undertake geotechnical and chemical soil testing to demonstrate re-engineered materials have been re-instated and comply with the specification.

A description of the earthworks is provided below in relation to phase 2.E East B.

DEL completed an excavation to design levels. The excavated material was transported to stockpiles SP34, SP35, SP42, SP43 and S3A, and placed as engineered fill in phase 2.2b where it was placed in loose lift layers ahead of in-situ processing. Excavated material was also placed as surcharge in 2.2b. Unacceptable material encountered during the works were removed from the works area and placed in stockpiles SP42 and SP51 (see section 2.2.8).Total volume of excavation was 24,000 m^3.

The works comprised placement of engineered fill of circa 33,450 m^3 of Class 2 (2A, 2C) material originating from stockpiles, surcharge removal in 2.3b and 2.2b as well as the excavations in zones 2.4d, 2.5a and 2.6b.

During earthwork activities, careful selection of excavated materials to be incorporated into the engineered fill was undertaken. Unacceptable materials, as described in the earthworks specification, found during excavation of the landfill were stockpiled separately and taken for further investigation and screening in a material processing area situated outside the phase.

Excavated materials were transported to the deposition area and spread in loose lift layers not exceeding 300mm using a GPS guided dozer. Materials were subject to mechanical raking followed by hand picking and segregation processes to remove any significant deleterious

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material (wood, plastic, organic matter etc.) and oversize fragments as per the earthworks specification. During processing, material was rotavated to break down particles and make the mass more homogenous. Further deleterious and oversize hand picking was undertaken after rotavation. Where necessary, lime or water was added to condition the processed soils and achieve near optimum moisture content.

2. Record of Works

2.1 Mobilisation and Set Up

DEL commenced the works on site on 20th of February 2017 with site set up including mobilisation and the establishment of site welfare facilities. Work commenced on Phase 2.4E East B with the excavation on 22nd September 2017. Fill operation relating to Linden Homes parcel was fully completed on 10th December 2019. Remaining works within the phase outside of the Linden Homes area, which includes the completion of engineered fill and surcharging are ongoing and will be reported as an update to this report.

With DEL acting as the Principal Contractor the site perimeter was secured through the installation of Heras fencing to separate site works from members of the public and other third parties, ensuring the site was secure.

A Construction Phase Health and Safety Plan was developed for the works, to include but not limited to the development of method statements, risk assessments and emergency procedures.

Plant and personnel were used to excavate, haul, place, process and compact material, consisting of;

Excavation:

- 20t – 50t Excavators were used to selectively excavate, segregate and load material onto articulated dump trucks.

Haulage:

- 25t articulated dump trucks, hauled material to the point of deposition.

Placement:

- CAT CS74B and CAT CP74B dozers (with Global Positioning System (GPS) capability to control layer thickness) spread out material to a nominal 300mm loose lift thickness.

Processing:

- Large obstructions were removed within the loose lift layers by dozers levelling out the material at the point of placement.
- Material was mechanically raked to break up and identify oversize.
- Material was rotavated to ensure that no further large obstructions were left in the loose lift layers and to homogenise it.

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- Manual labour assisted the mechanical plant to 'hand' pick deleterious materials over size and other unacceptable material, which was removed and transported via 8t dumper to a designated stockpiles (SP42 and SP51).
- Plant associated with the storage, placement and mixing of lime or water was also mobilized for use when necessary to control moisture content.

Compaction:

- Plant complying with the Specification for Highway Works, Volume 1, 600 Series, Earthworks, Table 6/1, Method 1 or 2, Ref. No. 8 and 10, comprising a combination of CAT CP74B pad-foot drum and CAT CS74B smooth drum rollers.

Surcharge:

- RSG plates were installed at the base of the engineered fill in accordance with the Engineering Specification drawings. Some RSGs were installed in areas of historic surcharge where no surcharge material was placed during these works.
- Surcharge material with an average bulk density of 1.95 was placed in accordance with the Engineering Specification.
- Surcharge was monitored by RSG and Piezometer instrumentation. They were monitored for a number of weeks. After which the surcharge was removed and monitored for heave.
- After the heave phase, the RSGs were reinstated with engineered fill in accordance with the Earthwork's Specification and the site brought up to the proposed BE drawing shown in the Earthworks Specification contract documents.

2.2 Description of Works Undertaken

2.2.1 Class 2 Engineered Fill Material Compaction Trial

A compaction trial commenced on 2nd March 2017 to demonstrate and prove the attainment of the end product criteria on the available site won class 2C materials (Made Ground) by trialling various compaction passes. The trial was completed on the 30th June 2017.

Full details of the compaction trial, results derived and the characterization of the material are included within the Compaction Trial Factual Report, issued 23rd April 2018 a copy of which is included within **Appendix C**.

During the trial, one compaction failure (exceeding 95% of Maximum Dry Density (MDD) was recorded after 8 passes using the combination of pad-foot and smooth rollers on layer 3 of panel 2. The failure was likely to have occurred due to the adverse weather conditions, causing over wetting of the material by leaving the layer exposed too long between the subsequent passes while allowing testing to take place. Taking the above into account, DEL considered that a compaction method (using 5 passes by pad-foot and 3 passed by smooth drum) would be the best approach to achieve the end product requirements. All California Bearing Ratio (CBR) tests achieved the required 3% CBR values.

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In summary, based on the compaction trial DEL adopted the following method to construct the permanent works:

- A placed nominal 300mm loose lift thickness with a total minimum of 8 passes (5 passes with CAT CP74B vibratory pad-foot drum roller and 3 passes with CAT CS74B smooth drum vibratory roller).
- Generated a nominal 250mm compacted layer, compliant with the contract specification.

Due to a substantial number of failures entering the main works prior to the 6th October 2017 on previous phases, for all phases after the 6th of October a total of 10 passes was adopted (6 passes with the CAT CP74B pad-foot drum vibratory roller and 4 passes with CS74B smooth drum vibratory roller) and the speed of the roller was reduced which reduced the number of failures entering the main works.

The ER, following inspection, would consider the information presented as either meeting with their general satisfaction or request corrective actions which would be recorded on the ITP pro-forma, or via correspondence and non-compliance notices.

2.2.2 Quality Control

A series of hold points were agreed with the ER, observing the placing, sorting, compaction and testing, to ensure that the layers of engineered fill met with their general satisfaction.

The hold points consisted of the following:

- **Hold Point 1**
  Inspection of the subgrade formation prior to the placement of fill (Excavation Formation Level).
  Hold Point 2
- Material was selectively dug from the source areas or stockpiles accordingly, visual deleterious or olfactory material (namely organic matter) and oversize materials, would be removed by the excavators and stockpiled away from the processing areas.
- **Hold Point 3**
  Material would be hauled and spread within the layer at the point of final placement and dozed out by a GPs dozer to achieve a nominal 300mm loose lift thickness, after which unacceptable materials and oversize as defined by the earthworks specification would be mechanically or manually removed and the layer would be rotavated to make the material more homogenous. The layer would be inspected by a DEL engineer to assess the need for moisture conditioning. To help inform such decision making an MCV sample would be taken and tested on site prior to compaction and the results compared to a target MCV range. Should moisture conditioning be required by the DEL engineer, this would be through the addition of water by tractor and bowser, or by the addition of lime by a custom-built spreader

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unit. Rotavation would be undertaken to mix the water or lime and the layer left to allow the conditioning to work. Bulk samples of the processed material would be sampled and surveyed for routine frequency testing by CET, an accredited geotechnical laboratory for geotechnical testing and by a DEL CQA Engineer for environmental testing to allow laboratory testing of the material to be undertaken in accordance with the specification.

- **Hold Point 4**
  The layer would receive compaction, with a minimum of 10 passes (6 passes with the CAT CP74B pad-foot drum vibratory roller and 4 passes with CS74B smooth drum vibratory roller.)
- **Hold Point 5**
  The compacted layer would undergo end product testing and alongside the routine frequency testing to determine:
  - % compaction relative to the Maximum Dry Density
  - % air voids ratio
  - Hand shear vane assessment
  - Geotechnical and chemical testing
  - In-Situ CBR and Plate Load Testing (final two layers only)

  The in situ test locations were surveyed and recorded on the DLP paperwork.
- **Hold Point 6**
  Final visual assessment of the layer and a photographic record of the layer.

DEL personnel would inspect the compacted and tested layer and compile the ITP paperwork. The ER would then be invited to inspect the layer and would consider the information presented as either meeting with their general satisfaction or not, and complete the ITP paperwork. If the layer did not meet their general satisfaction, DEL would undertake corrective actions, which would be recorded on the ITP documentation and the ER would be invited to recheck the layer and complete the ITP paperwork once the remedial actions and any associated retesting or sampling had been undertaken. Copies of the ITPs are included within **Appendix J.**

A reduced frequency of testing was undertaken in the RSG and soakaway reinstatement as described in Section 7.

A total of 18 notifications of non-compliant works were in place and relevant to phase 2.4E East B. Non-conformance notices are presented in **Appendix B** and summarised below**.**

Table 1 Summary of Non-Conformance Notices

NC	Notifications of non-compliant works	Action Taken
1	1. Lack of facilities relating to Drum Tests, gas monitoring and soakage tests 2. Lack of effective moisture control in earthworks	1. Provision for testing put in place by DEL 2. Use of MCV testing agreed and implemented as means of moisture control
2	Concerns raised by ER relating to the calibration and correlation of NDG	DEL implemented correlation method based on HA90/74 method. Due to high material variability, alternative methods of density measurement adopted

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3	1. High number of recorded failures and their relation to the use of NDG equipment 2. Late reporting of results 3. Ambiguity whether samples used for MDD target values are representative of the material tested	1.DEL provided an interim report outlining the interpretation of the target MDD values 2. Attempts made to use average target values. 3. Adoption of SRD as in situ density measurement
4	Unsatisfactory completion and reporting of the compaction trials. Results of the compaction trial do not support the compaction method used on site.	Compaction trial report revised and issued as part of the phase 2.2b report. Additional 2 passes applied to the method of compaction in the main works.
5	Sampling or sample processing not representative of the material subjected to field testing.	DEL and ER carried out audit of sampling and testing procedures.
6	Laboratory sedimentation analysis not undertaken by the specified method (pipette) by the contracted laboratory CET.	Contractor not accredited for pipette method, similar accredited method using hydrometer implemented. Additional soakaway tests may be required.
7	Collating and checking of chemical and FTOC results not undertaken by DEL causing delays in the data assessment	DEL implemented data collation and assessment.
8	Reliability of RSG data	Review of outstanding issues with explanations provided Comprehensive review of DEL QA/QC procedures with additional checking measures employed.
9	Damage to RSGs	Update to site procedures and additional demarcation around RSGs.
10	Removal of surcharge in lifts greater than 2m	DEL updated site procedures. Plant fitted with GPS equipment now used for surcharge removal.
11	QA and QC/ checking of RSG Data	Review undertaken by DEL of the QA/QC Procedures
12	Removal of RSG15 in 2.5B without instruction from Engineer	RSG15 reinstated and tracker implemented to record RSG status and associated instructions
13	Late reporting of geo-chemical trackers and lack of sufficient formatting resulting in not meeting the specification criteria	Tracker reporting improved and sent on a weekly basis including right formatting and identification of failed tests. NC Closed.
14	2.6BR14 not installed due to the significant depth of engineered fill without consultation with the Engineer to the contract. This should have been dealt with by means of RFI	2.6BR14A installed in an alternative location nearby as well as a near surface RSG at the required location 2.6BR14, following the RFI process. NC closed.
15	DEL not followed method statement for the processing and compaction of landscape fill.	DEL followed the method statement for landscape fill. Additional checks and audits in place until resolved
16	Two failures above 10% air voids in 2.6B	DEL re-tested the layers successfully and supplied a technical note. Laboratory test certificates to be updated to address inaccurate moisture content determinations. NC not applicable to phase 2.4E East B.
17	Frequency of surcharge SRD bulk density tests not met. Surcharge densities not achieved	DEL undertook additional surcharge BD tests. Progress impeded by inclement weather. Surcharge to be raised by ~800mm to mitigate potential for reduced bulk density surcharge. NC not applicable to phase 2.4E East B.
18	Heaters in the drum stores were not connected in October when a drop in temperature occurred	Heaters were connected the following week and NC closed.

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Final compliance for the earthworks is via this validation report and associated test results therein.

2.2.3 Description of Earthworks

Work commenced in Phase 2.4E East B with the cut on 22nd September 2017 and the placement of engineered fill relating to Linden Homes parcel was completed to finished bulk earthworks level on 10th December 2019. Fill operation, as well as the surcharge, in the remaining areas of the phase is ongoing and will be reported as an update to this report at a later date.

Original ground level was cleared of any surface vegetation through a shallow scrape to remove the vegetation and any rootlets associated with the vegetative matter, with the area then excavated down to the design levels (excavation formation level). Total volume of excavation to expose the design level was 31,150 m^3. Total volume of cut in the Linden Homes parcel was 24,000 m^3. Some of the material (circa 19,000 m^3) was used for the construction of engineered fill in phase 2.2b and surcharge in 2.2b. A total of 12,150 m^3 was hauled to stockpiles SP34, SP35, SP42, SP43 and S3A for further treatment and eventual re-use as general fill on the Kilnwood Site as a whole. No removal of topsoil was recorded.

The cleared ground was surveyed and visually inspected by DEL personnel to confirm that the base of excavation had been exposed and was free of deleterious material. It was then presented to the ER for inspection. Then the excavation formation was proof rolled using self-propelled vibratory rollers (CAT CS74B), generally comprising two dead rolls, to ensure no soft spots were present. After this, DEL personnel would inspect the proof rolled formation, address any soft spots or deleterious areas, survey the formation and compile the ITP paperwork. Following the inspection, the ER was invited to inspect and consider the information presented as either meeting their general satisfaction or not. If not DEL would undertake corrective actions which would be recorded on the ITP paperwork.

Following the successful presentation of the excavated formation level the excavation of exploratory validation trial pits and installation of monitoring equipment was undertaken as per the specification and is covered in section 6 of this report.

Then the placement of engineered fill took place. The base of excavation required an uplift through the placement of engineered fill to final finished design level (proposed bulk earthwork levels). Overall circa 33,450m^3 of material was re-engineered back within the phase 2.4E East B to date. The above volume is a total figure of Class 2A and 2C material (processed landfill).

Fill was placed in areas denoted as ‘panels’. These panels represent areas of fill placed processed and tested in a continuous operation.

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Due to the nature of the construction process these panels and associated Daily Layer Plans (DLPs) extend beyond the 2.4E East B boundary. Similarly, classification tests described in Section 5 are attributed to these layers or panels which can include test results located outside of the phase. These tests represent verification of continuous fill across the phase boundaries.

Landfill derived material was processed at the point of placement within the loose lift layers. Mixing of the material was undertaken via a number of stages / processes to provide a more homogeneous mass and to exclude unsuitable fractions, with the material visually inspected by DEL and the ER prior to completing the ITP paperwork. Details on the processing of the material are included within Section 2.2.8 below.

Some of the Class 2 soils were subject to moisture conditioning following processing in order to achieve the required compaction within the optimum moisture range. This was undertaken through the addition of small quantities of lime (0.5-1.5%) if the material was considered too wet by the DEL engineer, or by the addition of water in case the material was considered too dry. The quicklime would be spread from a custom-built spreader unit, with spread rates determined by the percentage to be spread, the density of the material, the layer thickness and the speed at which the spreader travelled. Check trays would be used to check the mass of material spread every morning, prior to works commencing.

The achievement of the contracts end product criteria would dictate the actual percentage of quicklime applied, with end product testing undertaken to verify compliance.

All layers were surveyed by the site team on completion, with the survey data presented within the accompanying layer plans. GPS surveys were undertaken with the accuracy of linear dimensions not exceeding 25mm. Maximum distance between spot levels did not exceed 15 metres. The co-ordinates of all sample and in-situ test locations were surveyed and recorded on an established grid to an accuracy of 1m.

Layer plans include locations of field verification tests. All samples and tests are also recorded in the ITP summary spreadsheet presented in **Appendix J.**

Further details on the quantities and locations of cut and fill are included within the daily layer plans and materials tracking summary sheets. The daily layer plans and materials tracking summary sheets can be found in **Appendix D** and **Appendix E** respectively.

Drainage of the area was achieved via the existing ditch running along the eastern boundary of phase 2.4E. Straw bales were installed on the downstream end of the ditch in order to prevent silt migration into the Bewbush brook. Details of the surface water management are included in the Construction Environmental Management Plan (CEMP) presented in **Appendix F**. Drainage controls were maintained throughout the duration of the works.

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Upon completion of the engineered fill, surcharge operations commenced as described in Section 6 and subsequent remediation of surcharging instrumentation as described in Section 7.

2.2.4 Formation Presentation and treatment of soft areas

The cleared excavation formation was visually inspected by DEL to confirm that design levels had been exposed and was free of unacceptable, soft or compressible material, and water. The ITP paper work would be compiled, and the ER invited to inspect the layer and document the inspection in the ITP paperwork.

Any identified soft spots or water, if present, was removed and brought up to level, rotavated and the area re-rolled as required. The ER following inspection would consider the information presented as either meeting with their general satisfaction or not. If not, DEL would undertake corrective actions which would be recorded on the ITP paperwork and the formation re-inspected.

2.2.5 Material Quantities

Material for placement within phase 2.4E East B was sourced from the following locations:

Table 2

Source	Volume (m^3)
Stockpiles SP4, SP29/41/35, SP26, SP55, SP56, SP60	11,750
Excavation in phases 2.4d, 2.5a, 2.6b	5,500
Removal of surcharge in phase 2.2b, 2.3b	16,200
Total	33,450

Total volume of fill placed in completed Linden Homes parcel was 23,200 m3 and is included in the above figures. Additional 4,000 m^3 of engineered fill will be placed in the areas outside the Linden Homes parcel in order to complete phase 2.4E East B. Verification of these works will be reported as an update to this report. Outstanding fill areas are shown in drawing 16525-318 presented in **Appendix M**.

2.2.6 Materials Movement Records

All material movements of soils from excavation to permanent placement have been tracked in accordance with the use of a materials management plan (MMP) as part of the CL:AIRE Definition of Waste Code of Practice. The MMP, was declared on 07/04/2017.

The Materials Movement Records Plans (MMR) describe cut area, placement area and volume detailed for each week of the works. MMR records were produced weekly, copies of which are included within **Appendix E.**

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Material was sampled as part of the routine frequency testing after it was processed at the point of placement or in relevant source stockpiles, with the number of samples sourced related to the volume of material processed each day in accordance with the specification. Details of chemical and Forensic Total Organic Carbon (FTOC) samples are listed in weekly MMR sheets. Unacceptable material stockpiles have been kept on site and no material has been taken off site. A waste management record comprising a chain of custody, receiving site's environmental permit, waste description, European Waste Catalogue Code and waste carrier's license will be provided in subsequent validation reports when unacceptable material is removed from site.

2.2.7 Weather Conditions

During the excavation and placement of materials within 2.4E East B, a total of 65 days were lost due to inclement weather (heavy rain/site allowed to dry following inclement weather). These are summarized in table 3 below:

Table 3 Inclement Weather Summary

Date	Number of days work lost due to inclement weather
October 2017	Total of 5 days
November 2017	Total of 2 days
December 2017	Total of 8 days
May 2018	Total of 1 day
June 2018	No inclement weather stoppages
July 2018	Total of 3 days
August 2018	Total of 3 days
September 2018	No inclement weather stoppages
October 2018	Total of 4 days
November 2018	Total of 7 days
December 2018	Total of 6 days
April 2019	Total of 2 days
May 2019	Total of 5 days
June 2019	Total of 3 days
September 2019	Total of 3 Days
October 2019	Total of 4 days
November 2019	Total of 8 days
December 2019	Total of 1 day

2.2.8 Material Processing

Excavated material was conditioned through a number of physical processes to produce a homogenous mass suitable for permanent inclusion within the main works. Material was processed at the point of final placement within loose lift layers. Each layer underwent the following physical screening and homogenization processes prior to compaction:

- Selective digging at the point of source (cut);

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- Spreading and levelling of the material using GPS equipped dozers and >20t excavators at the point of deposition;
- Mechanical disking using large diameter disks or raking towed behind a tractor
- Rotavation of the material using Virtigen and Bomag self-propelled rotavators.
- Hand picking

The specification required that the maximum diameter of any particle shall be no more than $^{2}/_{3}$ of the un-compacted layer thickness. Unacceptable material was removed during processing by a combination of mechanical and manual picking. Large obstructions were removed at the point of source by the excavators, such as timber posts, large lumps of concrete etc. Further large obstructions were identified and subsequently removed by the dozers levelling out the material within the processing layer. Areas of organic or potentially deleterious material were removed if encountered. A small volume (300 m^3) of unacceptable material was segregated and placed in stockpiles SP42 and SP51 (MMRs 37, 68 and 105 Drawings 16525-093; 16525-194 and 16525-283, Appendix E). The Unacceptable material stockpile has been kept on site and no material has been taken off site. A waste management record comprising a chain of custody, receiving site's environmental permit, waste description, European Waste Catalogue Code and waste carrier's license will be provided in subsequent validation reports when unacceptable material is removed from site. Where it was deemed necessary, lime was added (0.5% – 1.5%) for moisture conditioning purposes.

Each loose layer was rotavated to ensure that no further large obstructions were left in the placed layer prior to compaction and to add an additional degree of homogenisation. During rotavation an element of crushing is generated, with aggregates, gravels, brick and concrete often being broken down and larger particles reduced in size.

Prior to compaction of each layer, a nominated supervisor from DEL and the ER would undertake a walk over of the surface of the conditioned material, to ensure that it complied with the specification. The layer would be surveyed, ITP form generated and populated with the information relating to material processing.

Following the inspection, the ER would consider the information presented as either meeting with their general satisfaction or not. If not DEL would undertake corrective actions which would be recorded on the ITP paperwork.

On occasion, following inspection, it was necessary to further pick or rotavate the material prior to compaction, and the undertaking of further testing or sampling to demonstrate compliance with the specification which is recorded on the associated ITP.

Copies of the ITPs are included within **Appendix J**, along with photographic evidence of the walkover and inspection of the layer.

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2.2.9 Compaction of Fill

Following in situ processing of material at the point of placement, loose lift material was bladed by GPS equipped dozer in order to form layers not exceeding 300 mm in thickness. For each layer or for each 300m^3, a bulk sample was collected for MCV analysis. Depending on the outcome of the MCV test, further conditioning of material may have been necessary. This was undertaken by addition of lime in case of materials which were deemed wet of optimum, or by addition of water in case the material was too dry. In both cases the layer would have been rotavated in order to incorporate the modifying product evenly throughout the soil and time allowed for any reaction to take place. Once any necessary modification had been completed, further bulk samples in accordance with the specification were collected in the locations of pending field density tests and taken for laboratory analysis.

Compaction of the layer would then be undertaken by means of a minimum number of passes as described in hold point 4 in Section 2.2.2 above. After compaction was complete, in situ testing and a survey was undertaken before a final layer inspection would be undertaken by a DEL supervisor, the ITP paperwork completed and the ER invited to inspect.

3. Construction Environmental Monitoring

3.1 Environmental Results

Environmental monitoring of the site perimeters was undertaken during the works, to ensure that nuisance was not generated to offsite users through excessive dust, noise or odour.

For this purpose, six environmental monitoring stations were established around the perimeter of the site. Dust was monitored through the use of 'Frisbee' monitoring stations, with samples sent for external analysis on a fortnightly basis. Results are presented in **Appendix F.**

Environmental monitoring (dust, noise, odour and wind) was carried out during the project as a site wide exercise and for reporting purposes without any splits for different zones. An additional assessment was undertaken by a competent person, assessing dust using the following grading scale:

Table 4

1. None	**2. Slight**
No further action required, proceed with works.	Review working method, alter working method or areas being worked.
3. Moderate	**4. Severe**
Temporarily suspend works, change working method or areas being worked.	Halt operations immediately.

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Whilst undertaking the visual dust assessment, monitoring for noise, wind and odour was also undertaken. Copies of the assessments are included within **Appendix F**.

3.2 Gas Emissions Monitoring

3.2.1 Surface emissions monitoring

Surface emission mapping surveys by laser diode were carried out by a DEL appointed sub-contractor (Enitial), over the finished formation of the engineered fill to measure for potential landfill gas emissions. The 2.4E East B excavation formation emission surveys were carried out on 2 separate visits due to area access limitations. Visit 1 was carried out on the 5th of April 2018 and the second visit was carried out on the 26th of June 2018. The surveys were undertaken on a series of traverse lines spaced at 5m centres across the phase. Results of the survey are presented in Appendix G. No elevated concentrations were identified within the boundaries of 2.4E East B.

3.2.2 Borehole gas monitoring

There was no requirement to undertake borehole gas monitoring in the area of phase 2.4E East B. Borehole DCS1201 was relocated to grid S4 in Phase 2.4E West (RFI059).

3.2.3 Gas Validation Trial Pits

Three gas validation trial pits (DTP1213, DTP1216 and DTP1217) were excavated as shown in drawing 11950-2.4E-H-CE423-C5. Composite samples were collected from each trial pit to generate a drum test. Trial pits were backfilled with the arisings in order of excavation in accordance with the Earthworks Specification, as described in Section 7. Trial pit logs are presented in **Appendix G**. Drum teats results associated with the excavated material are presented in **Appendix L**. One drum test associated with DTP1213 was not undertaken.

4 Large scale gas generation tests (drum tests)

A total of 15 drum tests (DT189, DT195, DT197, DT206, DT207, DT208, DT214, DT215, DT218, DT221, DT222, DT263, DT283, DT285, DT287) were undertaken from the placed fill in the 2.4 E East B area at a frequency of 1/2,230 m^3. Monitoring of the gas emissions from the soils within the drums was undertaken twice weekly for approximately 14 weeks or more, as required by the specification.

Drums DT283, DT285 and DT287 are being monitored at the time of the issue of this report, results of which will be included as a final update to this report.

Drum testing has been undertaken as part of the routine test requirements. The location of each drum sample was surveyed and its source recorded on daily layer plans.

Monitoring of the drums was undertaken by DEL during which time, the drums were stored in a heated container to ensure the soils within the drums maintained a temperature greater than 10°C.

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During the sampling of each of the drums, a sample was taken for moisture content. The summary spreadsheet, detailing the drums moisture content, individual moisture content certificates and drum gas readings are included in **Appendix L.**

Gas related validation trial pits

Following formation excavation and prior to placement of engineered fill in phase 2.4E East B, 3 gas related trial pits (DTP1213, DTP1216 and DTP1217) were undertaken as instructed and overseen by CRH. The trial pits were excavated where previous site instigations had identified either elevated forensic TOC concentrations and / or elevated methane levels. The locations of these test pits are presented in drawing 16525-039 located in **Appendix G**. All trial pits were back filled in accordance with the earthworks specification as described in Section 7.

A drum sample, moisture content and composite FTOC sample was taken from the trial pit. FTOC and MC results are included in **Appendix L** of this report. A Log was undertaken in accordance with BS5930. The list of trial pits and corresponding drum test reference numbers can be found on the Drum Gas Monitoring Results Summary Spreadsheet. All drum monitoring results are presented in **Appendix L**.

5. Compliance Testing

5.1 Chemical Testing

Materials placed within the works have undergone laboratory based compliance testing via an MCERTS accredited laboratory supplier DETS Environmental Ltd (DETS) to demonstrate that the materials do not exceed the limiting values for contamination specified. Material was sampled for routine frequency testing by the CQA Engineer (DEL personnel) after it had been processed and met with the general satisfaction of the ER.

Chemical Analysis

The following frequency of chemical testing was undertaken on material placed within phase 2.4E East B. It should be noted that the depth of placed material varies across the area, therefore the volume should not be uniformly equated to the area.

Due to the nature of the construction operation, engineered fill was placed in panels which extend beyond phase boundaries from 2.4E East B into phases 2.6B and 2.4E West. As a result of this, the volumes quoted below comprise the total volume of material placed and tested, included that extending into adjacent phases as part of the panels described above. This total volume is used to establish testing frequencies of the fill placed as part of these works.

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Table 5

Material Class	No. of chemical tests	Specification Frequency	Actual Frequency	Volume of placed material
2	24	1/2,500m^3	2,133m^3	51,204m^3

The table below details the limiting values for harm to human health and the environment for the upper 2 m of engineered fill.

Table 6

Determinant	Units	Criteria for Upper 2.00m Engineered fill	Criteria for General fill 2.00m beneath final formation level	No. of samples Exceeding Criteria (Class 2)
Asbestos	% weight	<0.001	<0.1	0
Arsenic	mg/kg	37	N/A	0
Cadmium	mg/kg	26	N/A	0
Chromium (total)	mg/kg	910	N/A	0
Lead	mg/kg	200	N/A	1
Mercury (total)	mg/kg	40	N/A	0
Selenium	mg/kg	250	N/A	0
Nickel	mg/kg	180	N/A	0
Copper	mg/kg	2400	N/A	0
Zinc	mg/kg	3700	N/A	0
Benzo(a)pyrene	mg/kg	5.0	N/A	0
TPH Total	mg/kg	260	N/A	0
Aliphatic >C5-C6	mg/kg	42	N/A	0
Aliphatic >C6-C8	mg/kg	100	N/A	0
Aliphatic >C8-C10	mg/kg	27	N/A	0
Aliphatic >C10-C12	mg/kg	130	N/A	0
Aliphatic >C12-C16	mg/kg	1100	N/A	0
Aliphatic >C16-C21	mg/kg	1100	N/A	0
Aliphatic >C21-C35	mg/kg	1100	N/A	0
Aromatic C5-C7	mg/kg	70	N/A	0
Aromatic >C7-C8	mg/kg	130	N/A	0
Aromatic >C8-C10	mg/kg	34	N/A	0
Aromatic >C10-C12	mg/kg	74	N/A	0
Aromatic >C12-C16	mg/kg	140	N/A	0
Aromatic >C16-C21	mg/kg	260	N/A	0

Aromatic >C21-C35	mg/kg	1100	N/A	0
Phenols	mg/kg	120	N/A	0
Cyanide (total)	mg/kg	18	N/A	0
pH	Units	5 - 10	N/A	9

*Based on residential with plant uptake end use

Nine samples reported exceedances in pH, which coincide with periods of lime addition. Layers of engineered fill which received lime addition, including the percentage of lime added are identified in the ITP summary spreadsheet in **Appendix I**.

One sample (181008-B12DS-L24-3FTOC) reported the concentration of lead (Pb) of 880mg/kg which is above the specified criteria for the upper two metres of engineered fill. A 95th percentile analysis was undertaken in relation to lead showing the exceedance to pose a low risk with regard to the overall contaminant loading in the phase. Details of the analysis are presented in **Appendix H**.

Testing for water soluble sulphate, total sulphate, Sulphur and pH was also undertaken in accordance with TRL Report 447. During works within the phase, a small percentage of lime addition was introduced (up to 1.5%) to Class 2 material. Lime was added to approximately 12,000 m^3 of material placed in 2.4E East B. Lime addition was recorded in individual inspection test plans (ITP) presented in **Appendix J**. Table 7 below summarises TRL Report 447 tests. None of the TRL 447 samples reported total potential Sulphur (TPS) in excess of 1%.

Table 7

Test	No. of tests	Specification Frequency	Actual Frequency	Volume of placed material
TRL Report 447	16	1 / 3,000m^3	1/3,200m^3	51,204m^3

Forensic Total Organic Content (TOC) Testing

The following frequency of forensic TOC testing was undertaken on class 2 material placed within phase 2.4E East B. Due to the nature of the construction operation, engineered fill was placed in panels which extend beyond phase boundaries from 2.4E East B into phases 2.6B and 2.4E West. As a result of this, the volumes used to establish testing frequencies include the fill that extend into the adjacent phases. Material sourced from stockpile TS4 was tested at source.

Table 8 FTOC Test Summary

Test	No. of tests	Specification Frequency	Actual Frequency	Volume of placed material
Forensic TOC	95	1 / 500m^3	1/538m^3	51,204m^3

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Derivation of the TOC constituent components within the sample mass has been undertaken and no exceedances have been reported in the main works. One FTOC sample 180914-B12DS-L18-1 reported FTOC at 4.3% which is above the specified 4%. The sample represents a marginal exceedance and is located a depth of 4.5m below the final formation level. No remedial action was undertaken. Location of the sample is presented in 16525-037, **Appendix H**. The location is outside Linden Homes parcel. All Chemical and Forensic TOC results can be found within **Appendix H**.

5.2 Geotechnical Testing

5.2.1 Material Characterisation Testing

Materials placed within the works have undergone laboratory based and in-situ compliance testing via a UKAS accredited laboratory supplier CET to verify the materials compliance with the specification.

The following testing has been undertaken on Class 2C (Made Ground) material placed within phase 2.4E East B, which covers a total approximate volume of 33,450m^3 placed across an area of 11,775m^2. It should be noted that the depth of placed material varies across the area, therefore the volume should not be uniformly equated to the area.

Due to the nature of the construction operation, engineered fill was placed in panels which extend beyond phase boundaries from 2.4E East B into phases 2.6B and 2.4E West comprising 51,204m^3. As a result of this, the volumes quoted below and used to establish testing frequencies include the fill that extend into the adjacent phases.

The works were undertaken in a way where landfill material was excavated from the cut zone and transported to the area of final placement where a homogenisation process was undertaken as described in Section 2.2.8.

In accordance with the specification, where the materials have been processed at the point of final placement, a bulk sample of appropriate mass was collected at each in-situ density test location for a laboratory compaction test (OMC/MDD) using the 2.5kg rammer method, determination of particle density (PD) and determination of moisture content. The laboratory compaction test result was used to establish the maximum dry density (MDD) against which the % relative compaction (measured in-situ) was determined. The in-situ density test results, the particle density (PD) and the moisture content (MC) were used to calculate the air voids ratio.

Routine frequency testing was required for MC at 1/250m^3. MC, OMC/ MDD and PD were also required at each in situ density test determination. PSD was required at 1/1000m^3 with 1 per 5 gradings with sedimentation undertaken by pipette. PI was required are 1/1000m^3.

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Routine frequency testing for grading was changed with the effect on 10th November 2017 from 1/500 to 1/1,000m^3 (Engineers Variation EV12) and subsequently to 1/2,000m^3 in April 2019 (2.4-2.6 Specification revision E). In situ testing frequency was changed on the same date from one test per 35m x 35m to one test per 55m x 55m and in case of hand shear vane testing to 1 test per 70m x 70m. Note the specification revision is detailed in the 2.4-2.6 Specification revision E and adopted for phase 2.4E East B.

Routine frequency testing was obtained for MC at 1/419 m^3. MC, OMC/MDD and PD at a frequency of 1/682 m^3 in line with the in-situ test requirements of 1 test per 55 x 55m grid on each layer. Particle Size Distribution (PSD) was analysed at a frequency of 1/1,089 m^3 with sedimentation by hydrometer undertaken for 1 in every 5 PSD tests and Plasticity Index (PI) at a frequency of 1/3,200 m^3.

The contracted laboratory (CET) was not accredited for the use of the specified pipette method and the use of the alternative method not agreed with CampbellReith. Hydrometer method was used as an alternative and carried UKAS accreditation. CET reported that results obtained using hydrometer is within the acceptable error margins in comparison with the specified pipette method. NC 6 refers to the use of sedimentation by hydrometer instead of sedimentation by pipette.

Sampling for TRL Report 447 (pH, Total Sulphate, Water Soluble Sulphate and Total Sulphur), was required at a frequency of 1/3,000m^3. Testing for TRL Report 447 was undertaken and all other sampling was obtained after rotavation and moisture conditioning (if undertaken). Actual frequency of TRL testing was 1/3,200 m^3.

Moisture Condition Value (MCV) was used as a check of the moisture condition. From previous phases of the works and subsequent MCV Relationship results, a range of MCV values between 9 and 11 was established as representative values to indicate that Class 2 material would be at or near its optimum moisture content.

The table below provides a summary of the routine frequency testing undertaken from the processed materials at the point of placement.

Table 9 – Routine frequency testing undertaken from processed fill

Volume of material placed in 2.4E - East: 51,204 m^3			
Test	**No. of tests**	**Required Frequency**	**Actual Frequency**
Moisture Content (MC)	122	1 / 250 m^3	1 / 419 m^3
Moisture Condition Value (MCV)	243	1/250 m^3	1 / 210 m^3
Particle Size Distribution (PSD)	47	1 / 2,000 m^3	1 /1,089 m^3
PSD Sedimentation	16	1 / 10,000 m^3	1/3,200 m^3
Plasticity Index (PI)	46	1 / 2,000m^3	1 / 1,113 m^3

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Optimum Moisture Content / Maximum Dry Density (OMC/MDD)	75	1 / 3,025m^2	1 / 2,730^2
Particle Density (PD)	75	1 / 3,025^2	1 / 2,730^2
TRL Report 447	16	1 / 3,000m^3	1 / 3,200 m^3

A brief summary of the classification testing is provided below:

Moisture Content (MC)

MC values for routine frequency testing on Class 2 material prior to conditioning ranged from 12% to 31%, with an average of 18%. MC results were obtained from bulk samples prior to moisture conditioning, as well as after moisture conditioning. Values obtained after moisture conditioning were used to determine % compaction and air void ratio. MC values obtained after moisture conditioning ranged between 14% and 25%.

Particle Size Distribution (PSD)

Of the 47 samples analysed for PSD, 29 were reported as Class 2C and 18 as Class 2A/B - indicating that material placed within the works consists primarily of a Class 2C material, with the material as a whole exhibiting a cohesive characteristic (Class 2A/B or 2C).

A total of 16 sedimentation tests were undertaken by using the hydrometer method, reporting % passing 2 micrometres between 7 % and 26 %. The contracted laboratory (CET) was not accredited for the use of sedimentation by pipette method as required in the Specification and the use of the alternative method not agreed with CampbellReith as described in Section 5.2.

Plasticity Index (PI)

PI is derived through the determination of Plastic Limits (PL) and Liquid Limits (LL), with the Plasticity Index (PI) an index value of the LL – PL. A total of 7 tests were undertaken to date on the material used in 2.4E East B. PI values ranged from 14% to 24%, with an average value of 19%. No results returned a non-plastic result.

Moisture Condition Value (MCV)

A total of 243 MCV tests including retests were reported in the phase. MCV values for Class 2 material prior to conditioning ranged from 6.9 to 12.9, with an average value of 9.9. MCV results after conditioning ranged between 9 to 11.

Optimum Moisture Content / Maximum Dry Density (OMC/MDD)

A total of 75 samples were collected from processed material at the point of final placement. MDD values ranged from 1.61 Mg/m^3 to 1.81 Mg/m^3, with an average value of 1.72 Mg/m^3.

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Optimum Moisture Content (OMC) ranged between 14% and 21%, with an average value of 17.7%.

Particle Density (PD)

PD values were obtained from all samples collected from the processed material at the point of final placement. Values of reported samples ranged from 2.36 Mg/m^3 to 2.70 Mg/m^3, with an average value of 2.59 Mg/m^3.

5.2.2 In Situ Geotechnical Testing

The Earthworks Specification required end product testing for placed earthworks materials. The requirements were as follows:

- Placement of compacted material to achieve >95% Maximum Dry Density (MDD), with a corresponding presence of <10% air voids ratio along with >50kPa shear strength; and
- In-situ CBR on top 2 layers (0.50m) to be >3%.
- Plate Load CBR on the final formation to be >3%.
- Where Hydraulic Binders are used to reduce moisture content, a maximum allowable TPS of 1%.
- No more than 4% FTOC.
- Hydraulic permeability of less than 10^{-7} m/s.

The relative dry density requirement was deemed to have been achieved provided that at least 90% of the tests attained the specific dry density resulting in 95% compaction, and provided that no value fell below 93% compaction. In addition, the air voids ratio requirement was deemed to have been achieved provided that no value exceeded 10% AVR.

The Earthworks Specification requires In-situ field density tests to be undertaken 1 per 55m x 55m grid, or per layer or per day of earthworks (which ever gives the higher number of results) (see item 5.2.1). Representative bulk samples for OMC / MDD and PD were obtained and tested at each in-situ density test location, which equates to approximately 721m^3 from the processed material.

In-situ field density tests were undertaken by means of the sand replacement density test SRD.

Table 10 – In-situ Test Summary

Test	No. of tests	Equivalent Specification Frequency	Actual Frequency	Equivalent Area of Compacted Material

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% Compaction (maximum dry density) and Air Void Ratio (AVR)	71	1 / 756 m^3	1 / 721 m^3	2,884m^2
Hand Shear Vane (HSV)	74	1 / 1,225 m^3	1 / 711 m^3	3,084m^2

The above table excludes the original results from layers that were re-tested. Copies of all the test certificates for the geotechnical testing undertaken within Phase 2.4E East B can be found within **Appendix I**. Please note that due to the laboratory reporting format, there are some testing results included in the test certificates that relate to other Phases (2.6B and 2.4E).

% Compaction through field density testing: Sand Replacement Density SRD

Field density testing was undertaken on all compacted layers through a nominal 50m x 50m (x 250mm thick) grid. Compaction and air void ratio results for the SRD tests are summarized in **Tables 11 and 12** respectively.

Table 11 – SRD In-situ tests results summary - Compaction

Relative Compaction	No. of Results	Specification Percentage (%)	Actual Percentage (%)
>95%	69	90	99
95% - 93%	2	10	1
<93%	0	0	0

Table 12 – SRD in-situ tests results summary - Air Voids

Air Voids Ratio <2m	No of Results	Specification Percentage (%)	Actual Percentage (%)
<5%	71	90	100
>10%	0	0	0

Hand Shear Vane (HSV)

All reported HSV values comply with the specified requirement of >50kPa.The certificates reporting the SRD results are included within **Appendix I**.

In-Situ CBR via Plunger

In accordance with the specification DEL have undertaken in-situ CBR tests on the final 2 layers on a 35 x 35 m grid (1/1,225m^2). A total number of 2 in-situ CBR's were undertaken by plunger method on the top two layers of fill. Results reported 14.5% and 15.7%.

Plate Test CBR determination

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In addition, plate derived CBRs were carried out using a 300mm diameter plate on a 70m x 70m grid (4,900m^2). A total of 8 tests were undertaken reporting results between 3.6% and 10.0% with an average value of 6.8%. Certificates reporting the CBR results are included within **Appendix I**.

All geotechnical tests are summarised in the ITP tracker labelled *2.4E East B ITP Tracker* located in **Appendix I**. Test certificates located in **Appendix I** are labelled according to the CET report number which is unique to every CET report and can be found on the tracker alongside the test reference. In some cases, more than one test is included under the same CET report number.

Soakaway Permeability Tests

Soakaway permeability (infiltration) tests are required to be undertaken on a 100 x 100 metre grid in accordance with BRE Digest 365. One test (2.4E ST10) was undertaken in location indicated in the design drawing 11950-2.4E-H-CE423-C5. Results are presented in **Appendix I**.

One soakaway test (2.4E ES7) located outside the Linden Homes Development Parcel) is outstanding at the time of the issue of this report. This test will be reported on completion in the final update to this report.

5.3 Geotechnical Non-Compliances

Out of a total of 71 sand replacement results (excluding re-tests), there were 2 tests (comprising 1% of the total number of SRD results) reporting compaction values below 95%. The number of failed tests is within the 10% acceptable specified limits. Locations of the above tests are shown on drawing GEN-16525-033 in **Appendix M**.

6. Placement and Monitoring of Surcharge

Placement of surcharge was required as a form of geotechnical improvement in areas where made ground was not fully excavated in order to ensure that the resultant works meet the 'Performance Criteria'. This was achieved by loading of the existing made ground with surcharge and was sequenced following the partial completion of the construction of engineered fill. Effect of the surcharge was monitored through installed Rod Settlement Gauges (RSG) which monitored settlement and subsequent heave following the surcharge removal. Resultant pore water pressure was monitored by means of Vibrating Wire Piezometers (VWP). All instrumentation was installed prior to the commencement of the construction of engineered fill. The extent of completed surcharge panel 6A is shown in drawing 16525-258 in **Appendix M**.

Completed Panel 6a covers the Linden Homes Development Parcel 2F. The area within the Phase 2.4E East B, north of panel 6a, panel 6b is still under surcharge and construction, it will be reported following completion, in the final update of this report. Surcharge panel locations are presented in drawing 16525-258 in **Appendix M**.

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6.1 Permanent Datums

Two permanent datums (ND1 and New ND2) were installed in accordance with Figure 6 of BRE digest 386 (Monitoring Building and Ground Movement by Precise Levelling) prior to the installation of the monitoring stations. Datums were fixed into the natural strata by drilling into the rock head (Wield Clay Formation) to a depth in excess of six metres. Installation logs are presented in **Appendix K**.

Due to lack of existing benchmarks and survey stations in the vicinity of the works, level of datum *ND1* was established by levelling techniques with reference to the existing permanent datum *D1* installed during the previous phases. Level and positions of the new datums were measured three times in accordance with the specification. Loop measurements are presented in **Appendix K**.

6.2 Installation of Monitoring Equipment

Installation of monitoring instruments was required to monitor key parameters associated with historic surcharge. All monitoring equipment was installed in accordance with drawing 11950-2.4E/F/G/H-CE423-C5 (**Appendix A).**

6.2.1. Rod Settlement Gauges (RSG)

Rod Settlement gauges consist of a steel plate (300mm square) installed at the excavation formation level prior to the construction of engineered fill. Each plate had a welded BSPF socket by which it was connected to the reference rods. Extension rods were added when the level of the surrounding materials had been brought up to 250mm below the top of the preceding length. Levels were measured at the top of the rod. When the rods were extended, levels were measured immediately before and immediately after adding the extension.

Level monitoring was carried out by DEL staff throughout the works and on completion of surcharge construction for a period required by the engineer. A complete record of RSG level monitoring is presented in **Appendix K.** Summary of the RSG installations and completion dates of relevant phases of works is summarised in table 16 below.

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Table 16. RSG Summary

RSG Reference	Eng Fill Completion Date	Surcharge Placement Completion Date	Surcharge Removal Date	Surcharge Removal Completion Date
2.4ER23	28/05/2019*	29/05/2019	19/09/2019	10/10/2019
2.4ER24	20/05/2019*	24/05/2019	19/09/2019	10/10/2019
2.4ER28	23/05/2019*	07/06/2019	19/09/2019	10/10/2019
2.4ER29	13/05/2019*	29/05/2019	20/09/2019	14/10/2019

*Partial completion of engineered fill. Full height of the engineered fill was completed following the removal of surcharge in the Linden Homes parcel.

Details of surcharge installation and monitoring associated with the remaining panel 6b will be reported in an update to this report once complete.

6.2.2. Vibrating Wire Piezometers

Two vibrating wire piezometers were located in phase 2.4E East B, one of which (VWP10) was located within the Linden Homes parcel. Piezometer data is presented in **Appendix K**. Additional data relevant to piezometer VWP9 located in panel 6b will be reported in an update to this report once complete.

6.3 Placement and Removal of Surcharge

Placement of surcharge in phase 2.4E East B panel 6a was competed on 29/05/2019 as part of a wider panel 6. Panel 6A represents the area covered in Linden Homes Development Parcel 2F. The extent of the panel is presented in drawing 16525-258 in **Appendix M**. Bulk density measurement was undertaken by means of sand replacement test (SRD). A total of 39 SRD tests were undertaken in panel 6 as a whole with the average bulk density of 1.952 Mg/m^3. Surcharge bulk density certificates are presented in **Appendix K**. Surcharge in the remaining panel 6b which is outside the Linden Homes Parcel is still in place and will be reported in an update to this report following completion.

Surcharge removal from panel 6A was undertaken in two lifts between19/09/2019 and 14/10/2019. Surcharge removal was followed by a period of two weeks of heave monitoring. Level data associated with panel 6A is presented in **Appendix K**.

7 Reinstatement of Rod Settlement Gauges and Soakaway Pits

7.1 Decommissioning of Instrumentation Installations

A total of four RSG installations (2.4ER23, 2.4ER24, 2.4ER28 and 2.4ER29), two piezometers (2.4EP10 and 2.4EP11) and one soakaway pit (2.4ES10) were reinstated to date in phase 2.4E East B to facilitate completion of the Linden Homes Development Parcel. Reinstatement of

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instrumentation associated with panel 6b as well as soakaway 2.4ES7 will be undertaken following surcharge completion in the area and reported in an update to this report at a later date.

Decommissioning of RSG installations comprised a careful excavation of the RSGs which included removal of loosely compacted fill surround. Each excavation comprised a cut to formation exposing minimum 4m x 4m at excavation formation level. The formation was visually inspected by DEL personnel to confirm that the base of excavation had been exposed and was free of deleterious material. It was then presented to the ER for inspection. Then the excavation formation was proof rolled using self-propelled vibratory rollers (CAT CS74B), generally comprising two dead rolls, to ensure no soft spots were present. After this, DEL personnel would inspect the proof rolled formation, address any soft spots or deleterious areas, survey the formation and compile the ITP paperwork.

7.2 Installation and Soakaway Backfill

Backfill of each excavation was undertaken in accordance with the specification as described in section 2.2.9. Backfill material was sourced from the excavations and constitutes Class 2 material already processed during the initial earthworks. Some material was sourced from final trim to level across the engineered fill placed in adjacent areas. Generally, approximately 110 m^3 of engineered fill was placed per each backfilled RSG location. Accurate volumes are presented in daily layer plans and in the ITP tracker (2.4E East B Backfill Tracker) located in **Appendix N**.

Where additional processing was required, this would have taken place at the side of the excavation. Material processing is described in Section 2.2.8. For each 300m^3, a bulk sample was collected for MCV analysis. Depending on the outcome of the MCV test, further conditioning of material may have been necessary. This was undertaken by addition of water in case the material was too dry or lime in case of the material being wet of optimum. In both cases the material would have been rotavated in order to incorporate the modifying product evenly throughout the soil and time allowed for any reaction to take place. Details of moisture conditioning are described in Section 2.2.3. Between 0.5% and 1.0% of lime was required to be added during the installation backfill.

Engineered fill was placed in 300mm lose lift layers. Layer thickness was controlled by means of conventional surveying by DEL engineer who was in attendance during the backfill. Each layer was inspected by DEL engineer prior to being presented to the ER for inspection. Inspection record was kept on the relevant ITP form. One ITP form was used per backfill location. Once layers have been placed, further bulk samples in accordance with the specification were collected in the locations of pending field density tests and taken for laboratory analysis.

Compaction of each layer would then be undertaken by means of a minimum number of passes as described in hold point 4 in section 2.2.2 above. After compaction was complete, in situ testing and a survey was undertaken before a final layer inspection would be undertaken by a DEL supervisor, the ITP paperwork completed and the ER invited to inspect. ITP forms are presented in **Appendix N**.

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7.2.1 Compliance Testing

The material was sourced from previously placed fill and the chemical, FTOC and TRL testing required is included in the totals described in Section 5.1. Geotechnical testing was required as described in section 5.2. Material characterisation was undertaken through testing of bulk samples collected from the locations of the field density tests. These were undertaken at an approximate frequency of 1/49 m^3.

Test results for all installation backfill works as well as the backfill installation tracker are presented in **Appendix N**.

Table 17 – Summary of the Routine Frequency Testing (Installation Backfill)

Volume of material placed in Installation Backfill in 2.4E East B: 56 m^3				
Test	**No. of tests**	**Minimum Value**	**Maximum Value**	**Average Value**
Moisture Content (MC)	15	16%	23%	20%
Moisture Condition Value (MCV)	21	8.3	11.5	10.1
Particle Size Distribution (PSD)	7	-	-	-
PSD Sedimentation	-	-	-	-
Plasticity Index (PI)	7	20	24	22
Optimum Moisture Content / Maximum Dry Density (OMC/MDD)	15	15	20	17.8
Particle Density (PD)	15	2.50	2.62	2.58

In situ testing was undertaken as per the specification with the compliance requirements described in section 5.2.2. Hand shear vane tests (HSV) were undertaken on every compacted layer. Two field density tests (SRD) were undertaken per each backfilled installation at an approximate frequency of 1/49 m^3.

CBR tests were required on final two layers as per the specification, however only in the backfill locations which coincide with the proposed road corridors. Although some backfill locations in 2.4E East B did coincide with the proposed road corridors, installation backfill was undertaken on layers below the required depth for CBR determination. Final two layers of engineered fill were placed and tested as part of the general earthworks (see section 5.2.2).

Summary of in situ tests is presented in tables 18 and 19 below.

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Table 18. SRD In-situ tests results summary - Compaction

Relative Compaction	No. of Results	Specification Percentage (%)	Actual Percentage (%)
>95.0%	15	90	100
95.0% - 93.0%	0	10	0
<93.0%	0	0	0

Table 19 – SRD in-situ tests results summary - Air Voids

Air Voids Ratio <2m	No of Results	Specification Percentage (%)	Actual Percentage (%)
<5%	15	90	100
>10%	0	0	0

Hand Shear Vane Tests

All hand shear vane (HSV) tests reported results above specified 50kPa. Results of all in situ tests are available in **Appendix N**.

8 As Built Drawings

On completion of the Linden Homes parcel a 3D topographical survey referenced to ordnance datum was developed to enable a check against design.

The drawings have been produced in AutoCAD 2017 and Trimble Business Centre and can be viewed also in AutoCAD for full interpretation. AutoCAD files are included in **Appendix M**. The drawings include:

- Fill plan showing natural ground level and as built levels and contours including fill depths on a 15 x 15 m grid.
- Cut plan showing original ground level contours including cut depth.
- Plan showing completed areas.
- Indicative cross sections showing cut and completed fill layers.

As built drawings were produced to include completed areas in 2.4E East B. This currently comprises the Linden Homes development parcel 2F. Drawings relating to the outstanding works within phase 2.4E East B will be completed and submitted in the final report update following the completion of the works.

9 Conclusion

The works comprised a cut to the design base of excavation followed by placement of 33,450 m^3 of engineered fill to form a development platform. Within that is the completed Linden Homes parcel comprising a total of 23,200 m3 of engineered fill. Fill material was sourced

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from landfill excavations and processed in-situ prior to compaction. Verification of compacted material was undertaken with specified target parameters of 95% compaction and 10% air voids, alongside a permeability of 10^{-7} m/s and undrained shear strength of 50kPa as detailed in the CRH Earthworks Specification included in **Appendix B**.

A minimum CBR of 3% was required in the top two layers of engineered fill and a total combined Forensic TOC of 4% throughout the fill. Chemical and Asbestos tolerances are detailed in the section 5.1.

Sand replacement Density was used to determine field dry density. The following failures against the specification have been identified:

Out of a total of 71 sand replacement results (excluding re-tests), there were 2 tests (comprising 1% of the total number of SRD results) reporting compaction values between 93% - 95%. The number of failed tests is within the 10% acceptable specified limits.

Nine samples reported exceedances in pH, which coincide with periods of lime addition. Layers of engineered fill which received lime addition are identified in the ITP summary spreadsheet in **Appendix J**.

One sample (181008-B12DS-L24-3FTOC) reported the concentration of lead (Pb) of 880mg/kg which is above the specified criteria for the upper two metres of engineered fill. A 95th percentile analysis was in respect to lead showing the exceedance to pose a low risk with regard to the overall contaminant loading in the phase.

One sample 180914-B12DS-L18-1 exceeded the FTOC criteria of 4%. Sample is located at a depth of 4.5 metres below the final landform.

It is noted that this report covers the completed Linden Homes Development Parcel 2F, part of 2.4E East B. A final update to this report will follow in due course comprising full records for the remainder of the 2.4 E East B phase. Snagging items are listed below:

- Completion of surcharge monitoring relating to panel 6b
- Staged Removal of surcharge in panel 6b
- Heave monitoring relating to panel 6b surcharge
- Removal of surcharge relating instrumentation
- Reinstatement of voids created by the instrumentation removal by engineered fill and the associated testing in accordance with the specification
- Placement of remaining engineered fill (circa 4,000 m^3) and associated certification
- Completion of soakaway infiltration test

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