

TerraConsult

May 2015
Report No 2185R002-002

**WITHYHEDGE LANDFILL SITE
VALLEY CELL CONSTRUCTION WORKS
CONSTRUCTION QUALITY ASSURANCE
METHOD STATEMENT**

Prepared for
**RESOURCES MANAGEMENT UK LTD
Ltd**



**WITHYHEDGE LANDFILL SITE
VALLEY CELL CONSTRUCTION WORKS**

**Construction Quality Assurance
Method Statement**

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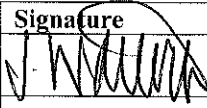
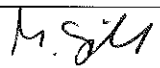
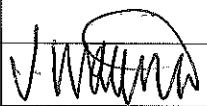
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DOCUMENT INFORMATION AND CONTROL SHEET

Document Status and Approval Schedule

Report No.	Title
2185R002-002	WITHYHEDGE LANDFILL SITE VALLEY CELL CONSTRUCTION WORKS CONSTRUCTION QUALITY ASSURANCE METHOD STATEMENT

Issue History

Issue	Status	Date	Prepared By	Signature	Date
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WITHYHEDGE LANDFILL SITE VALLEY CELL CONSTRUCTION WORKS CONSTRUCTION QUALITY ASSURANCE METHOD STATEMENT

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DOCUMENT REVISION CONTROL SHEET

Report No.	Title
2185R002-002 13 May 2015	Withyhedge Landfill Site Valley Cell Construction Construction Quality Assurance Plan

Item Reference	Description
2.1.8	Text revised to read in accordance with the permit condition 2.6.3
2.1.17	Text revised to state that the borehole decommissioning QAP is included in this QAP
3.1	Text included to state that the cell swill be developed progressively and separately
4.1 (vi)	Text revised to state that surveys will pick up the target pad formation as built details
4.1 (vii)	New paragraph included to state that the existing cell liner edges will be inspected for damage.
4.1 (viii)	New paragraph included to state that the existing sidewall riser located within the Cell 1 south / Cell S1 edge is to be decommissioned.
4.1 (ix)	New paragraph included to state that the CQA Engineer will ensure that the existing environmental monitoring boreholes located within the footprint of the valley cells are decommissioned in compliance.
5.1 (iii)	Revise the text to state that the source evaluation report is to be submitted to NRW but it will not go through the review / acceptance procedure.
7.1 (xi)	Revise the text to ensure that a subgrade approval record is prepared and signed off prior to the FML being deployed across the GCL surface.
9.3	Section inserted to cover the installation of two sidewall riser pipes.
9.4	This paragraph / section applies to the Cell 13 chamber works.
10	Section not required and deleted
13.2 (viii) & (ix)	Items to be included into the validation report added to the text.
Drawings	Drawing 2185/2/008 – Overflow Details deleted Drawing 2185/2/009 – Cell 13 Leachate Chamber added
Appendix C – CQA Programme Tables	All the above changes have been reflected in the tables included at Appendix C.
Appendix G	Appendix G added to include example CQA record forms

WITHYHEDGE LANDFILL SITE VALLEY CELL CONSTRUCTION WORKS QUALITY ASSURANCE METHOD STATEMENT

1. INTRODUCTION

1.1 General

- 1.1.1 This CQA Method Statement details the CQA measures to be undertaken by Resources Management UK Ltd (RML) at the Withyhedge Landfill Site, for the proposed Valley Cell construction works specifically entailing earthworks, cell lining and drainage works.
- 1.1.2 The Works will be undertaken by RML. TerraConsult Ltd (TerraConsult) has been appointed as CQA Engineer and independent third party consulting engineer to supervise and control the works on RML's behalf. Conformance testing shall be undertaken at approved, UKAS accredited geosynthetic and geotechnical testing laboratories.
- 1.1.3 This document represents the Construction Quality Assurance (CQA) Method Statement for the Works. This CQA Method statement has been compiled with reference to the Specification which is included at Appendix A. Appendix C contains the CQA Programme presented as a series of tables.

1.2 Definitions

- 1.2.1 For the sake of clarification the following definitions are given:
 - **Construction Quality Assurance (CQA):** Means “a planned and systematic pattern of all means and actions designed to provide confidence that items or services meet contractual and regulatory requirements, and will perform satisfactorily in service.”. Construction Quality Assurance refers to means and actions employed by the CQA Engineer, to assure conformity of the preparation, production and installation of this CQA Method Statement, the Contract Drawings, and Specification. CQA is provided by TerraConsult.
 - **Construction Quality Control (CQC):** Means “those actions that provide a means to measure and regulate the characteristics of an item or service to contractual requirements.”. Construction Quality Control refers to those actions taken by Manufacturers, Installers, Contractors, or the Employer to ensure that the materials and the workmanship meet the requirements of the Contract Drawings and Specifications.
 - **Employer:** Means “the person or persons, firm or company or other body whom own and have responsibility for the facility.” The Employer for the works at Withyhedge Landfill Site is Resources Management UK Ltd.
 - **Contractor:** Means “the person or persons, firm, company or other body to whom the contract has been awarded by the Employer, and includes the Contractor's personal representatives or other parties, e.g. Sub-contractors, Manufacturers.” The Contractor for the works at Withyhedge Landfill Site is Resources Management UK Ltd.

- **Specification:** Means “that part of the Contract entered into between the Employer and the Contractor, which sets out the Employer’s detailed requirements as to how the works should be constructed, tested, measured and quality assured.”

2. CONSTRUCTION QUALITY ASSURANCE (CQA)

2.1 Introduction

2.1.1 This CQA method statement forms part of the Specification for the construction of a landfill liner and leachate drainage system for the Valley Cell.

2.1.2 The measure of a successful outcome for the project is acceptance of CQA validation of the Works by the Natural Resources Wales (NRW). The CQA Engineer shall undertake the tasks specified in this document to ensure that the highest standards of performance are met and that the lining system is satisfactory in every respect.

2.1.3 This CQA Method statement describes the functions of the CQA Engineer for the construction of the liner system including the minimum required quality assurance testing regime. The CQA Engineer shall:-

- a) Develop a suitable CQA method statement which is practical, achievable and ensures the highest standards of environmental protection.
- b) Supply a CQA Engineer to site to provide full time supervision and quality assurance of the lining works in accordance with this CQA method statement to ensure compliance with the Specification.
- c) Produce and submit a validation report upon completion of the whole or part of the proposed Works as required.

2.1.4 Staff from TerraConsult shall act as the CQA Engineer and shall carry out Construction Quality Control during the construction of the cell. All personnel shall have relevant experience in landfill construction and earthworks control. The anticipated personnel to be involved in the works are listed below but suitable substitution, using personnel with equivalent experience may be made due to unavailability:

- TerraConsult project manager – Jim Waterworth BSc CGeol FGS (Director)
- TerraConsult CQA engineer – TBA

2.1.5 The main duties of the CQA Engineer shall be:

1. to supervise the construction of the cell liner to ensure compliance with all conformance aspects of the Specification;
2. to assess the Contractor’s documentation for material suitability and arrange CQA testing
3. to supervise all surveying or other such procedures involved in the lining system control;
4. to keep full daily records of all site operations, testing and site conditions.

- 2.1.6 The name and qualifications of the proposed TerraConsult CQA engineer shall be submitted to the NRW for approval.
- 2.1.7 Only staff approved by the NRW shall form the CQA Team. Proposed changes to the CQA staff shall be notified to the NRW.
- 2.1.8 In accordance with EP condition 2.6.3 – The construction of the new cell/s shall take place only in accordance with the approved construction proposals unless:
- a) Any change to the approved construction proposals would have no impact on the performance of any element of the design; or
 - b) A change has otherwise been agreed in writing by the NRW.
- 2.1.9 The CQA Engineer shall inform the NRW prior to the commencement of work on site.
- 2.1.10 The CQA Engineer shall review the Contractor's method statements for each element of the works, provide acceptance to the Contractor following any revisions that may be necessary.
- 2.1.11 The TerraConsult CQA Engineer shall report daily to the TerraConsult project manager and report any unusual or unexpected occurrences immediately for discussion and/or direction.
- 2.1.12 The CQA Engineer shall keep and maintain a daily record of the progress of the Works, which shall include but shall not be confined to the list of items below. The records will be made available for inspection by representatives of the NRW.
- a) date
 - b) weather conditions
 - c) delivery of materials
 - d) plant and labour
 - e) roll numbers deployed
 - f) panels installed
 - g) areas of non-conformance
 - h) clay placement/compaction/in situ testing
 - j) samples taken
 - k) repairs
 - l) CQA installation checklist
 - m) site meetings
 - n) progress photographs (which shall record all major construction elements of the project)
- 2.1.13 The daily records shall be used to provide certification of the preparatory and engineering works and shall be made available to the NRW when required.
- 2.1.14 Staff from the NRW shall be given the opportunity to visit the site throughout the work to appraise themselves of progress and check any of the items being measured. The CQA Engineer shall regularly keep the NRW updated as to the progress of work on site. Wherever possible the CQA Engineer shall liaise with visiting NRW staff so that no misunderstanding of the reason for actions of site staff arises.

2.1.15 All laboratory testing shall be undertaken by laboratories specifically accredited by UKAS for the test being undertaken unless otherwise agreed by the CQA Engineer and the NRW

2.1.16 All non-compliances shall be reported to the NRW at the time that the non-compliance occurs.

2.1.17 The CQA Engineer shall ensure that the decommissioning and sealing of boreholes BH21, BH22 and BH23 is completed in accordance with **this** QA plan. The records for which shall be included in the validation report.

2.2 Daily Meeting

2.2.1 A daily meeting shall be held on site between the CQA Engineer and the Contractor's representative.

2.2.2 The purpose of the daily meeting is to:

- (i) review the work activity and location for the day;
- (ii) note the Contractor's installation personnel for the day/shift;
- (iii) review the previous days work activity;
- (iv) review the work schedule;
- (v) discuss any interfacing with other contractors/site operations;
- (vi) discuss/highlight any problems and solutions.

2.3 CQA Handover & Absence Protocol

Defined protocol to control all changes in CQA Engineer and provide instruction in the event of uncontrolled absence is presented within Appendix C CQA Programme Tables

3. DESCRIPTION OF THE WORKS

3.1 The works comprise installation of a composite geosynthetic and mineral lining system incorporating leachate drainage and control. **It is envisaged that the cells will be developed separately from the north of the site, moving south in the sequence N1, N2, N3 then S1.**

4. FORMATION LAYER AND GENERAL BACKFILL

4.1 The CQA Engineer shall:

- (i) ensure that all material deemed unsuitable in accordance with the Specification is removed to an area agreed with the Site Manager and not used in the works;
- (ii) ensure that only suitable materials are used where required as engineered fill;
- (iii) ensure all areas of non-compliance are remediated in accordance with the Specification;

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- (iv) provide written certification to the Contractor that the surface on which the Engineered Clay is to be installed is acceptable prior to installation. Written certification may be withdrawn in the event of surface deterioration by any cause and only re-issued by the CQA Engineer upon remedial works being compliant with the Specification;
 - (v) ensure that the Contractor's survey is carried out on completion of the prepared formation in accordance with the CQA survey requirements detailed at Clause 2.4 of the Specification to confirm that the requisite levels have been attained;
 - (vi) ensure that the formation surfaces and the sumps excavated for the leachate extraction chambers and monitoring points, including for the works associated with the target pad formation levels are picked up by detailed survey, in accordance with the Specification;
 - (vii) undertake a careful inspection to confirm that the construction of the temporary cap to Cells 1&2 North and South had not damaged the basal lining system around the area of the tie-in. A record shall be kept in the daily diary and repairs, if required, shall be completed in accordance with the relevant sections in this document.
 - (viii) Ensure that the existing upslope riser located at the southern edge of Cell S1, within Cell 1 South is decommissioned in accordance with the specification.
 - (ix) Ensure that the existing boreholes BH21, BH22 & BH23 are decommissioned in accordance with the specification.
- 4.2 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme – Formation Layer presented at Appendix C and are presented in the CQA Validation Report.

5. ENGINEERED CLAY LINER (ECL)

5.1 The CQA Engineer shall:

- (i) review the results of the laboratory testing carried out on the proposed source materials to ensure compliance with the Specification and ensure that the material proposed to form the ECL is tested in accordance with the CQA Programme presented at Appendix C for source testing and ensure that the results of the source testing are used to confirm that the proposed source material is the acceptable;
- (ii) ensure large scale shear box testing has been completed and the results meet the requirements of the specification.
- (iii) submit the source test results to the NRW for their records and issue a source acceptance notification to the Contractor prior to its use on site;
- (iv) ensure that only suitable materials are used where required as ECL;

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- (v) ensure that a trial liner is undertaken for each source of clay used, in accordance with the requirements set out in the Specification on the cell base and against the sidewalls;
 - (vi) ensure that a trial liner is carried out if the plant used for the compaction of the ECL is changed at any time during the Works;
 - (vii) provide verbal approval to the Contractor that the surface on which the ECL is to be installed is acceptable prior to construction. Approval may be withdrawn in the event of surface deterioration by any cause and only re-issued by the CQA Engineer upon remedial works being compliant with the Specification
 - (viii) monitor the placement and compaction of the clay ensuring that the works are carried out in accordance with the Specification and the agreed Contractor's method statement taking into consideration the results of the trial liner;
 - (ix) maintain an ongoing record of the quantity and or layer / liner area of ECL completed at any one time in order to check that the frequency of CQA compliance tests as specified in the CQA Programme attached at Appendix C is being achieved;
 - (x) undertake CQA compliance testing in accordance with the CQA Programme detailed at Appendix C;
 - (xi) ensure all areas of non-compliance are remediated in accordance with the Specification and recorded in accordance with the CQA Programme attached at Appendix C;
 - (xii) provide approval of the final surface of the ECL as having been prepared in accordance with the requirements of the Specification;
 - (xiii) ensure that the Contractor's survey is carried out on the prepared formation surface and following completion of the ECL (including for leachate extraction chamber and monitoring points) in accordance with the frequency detailed in the Specification and confirm that the requisite thicknesses, levels and gradients have been attained.
 - (xiv) ensure that an additional or check survey is undertaken by a surveyor independent of the Contractor of the thickness of the ECL to check the accuracy of the Contractor's survey, using the same grid points.
 - (xv) ensure that the sumps for the leachate extraction chambers and monitoring points are excavated and lined with clay in accordance with the Specification.
 - (xvi) ensure that the leachate extraction chambers and monitoring points are constructed using materials and products compliant with the Specification.

5.2 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme presented at Appendix C and that the records are presented in the CQA validation report.

6 GEOSYNTHETIC CLAY LINER (GCL)

6.1 The CQA Engineer shall:

- (i) ensure that the GCL proposed to be supplied meets the requirements of the Specification;
- (ii) ensure large scale shear box testing has been completed and the results meet the requirements of the specification.
- (iii) review and provide acceptance of the Contractor's manufacturer's quality control documentation and pre-installation information including method statement, panel layout, field quality control forms, ensuring that the information is in accordance with the Specification;
- (iv) ensure that the Contractor attends a pre-start meeting and that matters arising are dealt with in accordance with the Specification or brought to the attention of the NRW for agreement;
- (v) assess the QC data sheets to confirm that the material supplied meets the requirements of the Specification, prior to installation;
- (vi) ensure that each roll of GCL delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification and that CQA is carried out in accordance with the CQA Programme attached at Appendix C;
- (vii) take samples of the GCL and arrange for conformance testing in accordance with the Specification and the CQA Programme attached at Appendix C.
- (viii) assess the conformance test results and confirm whether the requirements of the Specification have been met;
- (ix) ensure that the GCL is deployed on a compliant subgrade surface and that it is weighted down in accordance with the agreed Contractor's method statement and or the Specification;
- (x) ensure that the GCL is deployed in accordance with the Specification using agreed, acceptable methods and record the methods used;
- (xi) ensure that the GCL deployed meets the requirements of the Specification for condition, panel layout, seam overlap and accessory bentonite seaming;
- (xii) ensure that deployment and seaming takes place only in compliant weather conditions and that the GCL is covered, secured and protected in accordance with the requirements of the Specification;
- (xiii) instruct appropriate repair work in accordance with the Specification and ensure that the repair work is completed, tested and is compliant, in accordance with the Specification;

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- (xiv) ensure that the Contractor undertakes surveying in accordance with the requirements set out in the Specification and that the results of the surveying meet the needs for the production of a validation report;

6.2 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme attached at Appendix C and that the records and test results are presented in the validation report.

7 HIGH DENSITY POLYETHYLENE FLEXIBLE MEMBRANE LINER (HDPE FML)

7.1 The CQA Engineer shall:

- (i) ensure that the FML proposed to be supplied meets the requirements of the Specification;
- (ii) ensure large scale shear box testing has been completed and the results meet the requirements of the specification.
- (iii) review and provide acceptance of the Contractor's pre-installation information including method statement, panel layout, field quality control forms, ensuring that the information is in accordance with the Specification;
- (iv) ensure that the Contractor attends a pre-start meeting and that matters arising are dealt with in accordance with the Specification or brought to the attention of the NRW for agreement;
- (v) ensure that all rolls delivered to site are accompanied by a manufacturer's QC data sheet, covering the minimum required information as listed in the Specification;
- (vi) assess the QC data sheets all to confirm that the material supplied meets the requirements of the Specification, prior to installation;
- (vii) ensure that each roll of FML delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification and that CQA is carried out in accordance with the CQA Programme attached at Appendix C;
- (viii) ensure that all welders are accredited in accordance with the requirements of the Specification;
- (ix) take samples of the FML and arrange for conformance testing in accordance with the Specification and the CQA Programme attached at Appendix C.
- (x) assess the conformance test results and confirm whether the requirements of the Specification have been met;
- (xi) ensure that the FML is deployed on a compliant subgrade surface, **that this is confirmed in writing on a subgrade approval record** and that the FML is weighted down (temporary surcharge) in accordance with the agreed Contractor's method statement and or the Specification;

- (xii) ensure that the FML is deployed in accordance with the Specification by the specified, accredited technicians using agreed, acceptable methods and record the methods used;
 - (xiii) ensure that the FML deployed meets the requirements of the Specification for condition, thickness, panel layout and seam overlap;
 - (xiv) ensure that all pre-weld tests and trials are carried out and are compliant with the Specification;
 - (xv) ensure that seaming takes place only after compliant pre-weld trials, in compliant weather conditions and on compliant sheet and seam conditions;
 - (xvi) ensure that all seams and welds undergo the appropriate non-destructive and destructive testing in accordance with the Specification and that the results are compliant;
 - (xvii) instruct appropriate repair work in accordance with the Specification and ensure that the repair work is completed, tested and is compliant, in accordance with the Specification;
 - (xviii) ensure that the Contractor undertakes surveying in accordance with the requirements set out in the Specification and that the results of the surveying meet the needs for the production of a validation report.
- 7.2 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme attached at Appendix C and that the records and test results are presented in the validation report.

8 PROTECTIVE GEOTEXTILE

8.1 The CQA Engineer shall:

- (i) ensure, through an assessment of the product data sheet and a review of the cylinder testing results and large scale shear box test results provided that the geotextile proposed to be supplied meets the requirements of the Specification and provide approval;
- (ii) assess and approve a method statement submitted by the Contractor for the supply and installation of the geotextile;
- (iii) ensure that the Contractor provides the pre-installation information in accordance with the Specification;
- (iv) ensure that the Contractor attends a pre-start meeting and that matters arising are dealt with in accordance with the Specification or brought to the attention of the NRW for agreement;

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- (v) ensure that all rolls delivered to site are accompanied by a manufacturer's QC data sheet covering the minimum required information as listed in the Specification or a statement of compliance with CEN requirements;
 - (vi) assess the QC information to confirm that the material supplied meets the requirements of the Specification;
 - (vii) ensure that each roll of geotextile delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification and that CQA is carried out in accordance with the CQA Programme attached at Appendix C;
 - (viii) take samples of the geotextile and arrange for conformance testing in accordance with the Specification and the CQA Programme attached at Appendix C.
 - (ix) assess the conformance test results and confirm whether the requirements of the Specification have been met;
 - (x) ensure that the geotextile is deployed on a compliant subgrade surface and that it is weighted down (temporary surcharge) in accordance with the agreed Contractor's method statement and or the Specification;
 - (xi) ensure that the geotextile is deployed in accordance with the Specification using agreed, acceptable methods and record the methods used;
 - (xii) ensure that the geotextile deployed meets the requirements of the Specification for condition, panel layout and seam overlap;
 - (xiii) ensure that deployment and seaming takes place only in compliant weather and seam conditions;
 - (xiv) instruct appropriate repair work in accordance with the Specification and ensure that the repair work is completed and is compliant, in accordance with the Specification;
 - (xv) ensure that the Contractor undertakes surveying in accordance with the requirements set out in the Specification and that the results of the surveying meet the needs for the production of a validation report;
 - (xvi) verify that the installation of the protective geotextile is completed to the requirements of the Specification and CQA Method statement, including any repairs, prior to granting approval for the placement of the leachate drainage layer;
 - (xvii) ensure that the placement of the leachate drainage layer is not permitted until the results of all preceding CQA testing are available and the results indicate that the ECL, FML and protective geotextile have been installed in accordance with the requirements of the Specification.

8.2 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme attached at Appendix C and that the records and test results are presented in the validation report.

9 LEACHATE COLLECTION & CONTROL SYSTEM

9.1 General Matters

The CQA Engineer shall assess and approve a method statement submitted by the Contractor for the installation of the items of the leachate collection and control system;

9.2 Leachate Drainage Aggregate

The CQA Engineer shall:

- (i) ensure that the Contractor supplies quality control test results carried out on the quarry product proposed to form the leachate drainage aggregates in accordance with the requirements of the Specification;
- (ii) assess the quality control test results provided by the Contractor to ensure that the proposed aggregates meet the requirements of the Specification and provide approval prior to delivery to site;
- (iii) collect representative samples of the aggregates and arrange for compliance testing in accordance with the Specification and the CQA Programme attached at Appendix C;
- (iv) assess the results of the compliance testing and confirm whether the requirements of the Specification have been met;
- (v) continuously monitor aggregate placement operations ensuring that the characteristics of the material do not change and that the lining system is not compromised;
- (vi) ensure that the aggregate is placed in accordance with the Specification using agreed, acceptable methods, in accordance with the accepted method statement and record the methods used;
- (vii) ensure that aggregate is placed to areas and at levels as shown on the Drawings at a thickness equal to or greater than the minimum allowable thickness by careful probing / mini trial pits at regular intervals (25m) prior to the Contractor's survey;
- (viii) ensure that the Contractor undertakes surveying in accordance with the requirements of the Specification and that the results of the surveying meet the needs for the production of a validation report;

9.3 Leachate Drainage Pipework

The CQA Engineer shall:

- (i) ensure that the Contractor provides the product details with supporting calculations on the product/s proposed for each diameter of pipe to be used to form the leachate drainage pipework in accordance with the requirements of the Specification;

- (ii) assess the product details and supporting calculations to ensure compliance with the requirements of the Specification for each diameter of pipe to be used;
- (iii) ensure that all pipework associated with the leachate collection system is delivered, stored and handled in accordance with the manufacturer's recommendations and or Specification;
- (iv) ensure that the pipework is installed at the locations shown on the relevant Drawings;
- (v) ensure that the pipework joints are constructed in accordance with the Specification;
- (vi) ensure that where butt-welding techniques are applied that a fully automatic machine is used which operates to meet the requirements listed in the Specification and provides the information listed in the Specification; the CQA Engineer shall ensure that the welding records and information are provided in accordance with the Specification;
- (vii) ensure that where electrofusion couplers are used that the methods and equipment detailed in the Specification are used to meet the requirements listed in the Specification and provides the information listed in the Specification; the CQA Engineer shall ensure that the welding records and information are provided in accordance with the Specification;
- (viii) ensure that the pipe installation, pipe bedding and gravel haunch over the pipework is in accordance with the Specification;
- (ix) ensure that the Contractor surveys the level of the top of the pipework and the end points of each drainage pipe.

9.4 Leachate Chamber, Monitoring Points & Target Pads (including Cell 13 Chamber)

The CQA Engineer shall:

- (i) witness and record the location and the method of construction of the leachate collection chambers, leachate monitoring points and target pads ensuring compliance with the Specification. Particular attention should be paid to the placement of reinforcement and the appropriate use of a vibrating poker in removing air bubbles from all cast in-situ concrete;
- (ii) ensure that the Contractor surveys the as built position, layout and extent and level of the leachate collection chambers, leachate monitoring points and target pads;

9.5 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme attached at Appendix C and that the records are presented in the validation report.

10 FILTER GEOTEXTILE

Section deleted.

11. GEOCOMPOSITE DRAINAGE LAYER (GDL)

11.1 The CQA Engineer shall:

- (i) ensure, through assessment of the QC data sheets, that the geocomposite drain proposed to be supplied meets the requirements of the Specification;
- (ii) review and provide acceptance of the Contractor's manufacturer's quality control documentation and pre-installation information including method statement, ensuring that the information is in accordance with the Specification;
- (iii) ensure that each roll of geocomposite drain delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification and that CQA is carried out in accordance with the CQA Programme attached at Appendix C;
- (iv) take samples of the geocomposite drain and arrange for conformance testing in accordance with the Specification and the CQA Programme attached at Appendix C.
- (v) assess the conformance test results and confirm whether the requirements of the Specification have been met;
- (vi) ensure that the geocomposite drain is deployed on a compliant subgrade surface and that it is weighted down in accordance with the agreed Contractor's method statement and or the Specification;
- (vii) ensure that the geocomposite drain is deployed in accordance with the Specification using agreed, acceptable methods and record the methods used;
- (viii) ensure that the geocomposite drain deployed meets the requirements of the Specification for condition, panel layout, seam overlap and seam ties;
- (ix) ensure that deployment takes place only in compliant weather conditions and that the geocomposite drain is covered, secured and protected in accordance with the requirements of the Specification;
- (x) instruct appropriate repair work in accordance with the Specification and ensure that the repair work is completed and is compliant, in accordance with the Specification;

11.2 The CQA Engineer shall ensure that all elements of the pressure relief drain are documented according to the CQA Programme attached at Appendix C and that the records and test results are presented in the validation report.

12 ELECTRICAL RESISTIVITY LEAK TESTING SURVEY (ERLTS)

12.1 The CQA Engineer shall:

- (i) ensure that prior to commencement of the ERLTS the Contractor has provided a method statement for undertaking the survey including the names and relevant experience of the personnel involved;
- (ii) ensure that the method statement meets the requirements of the Specification;
- (iii) witness that conditions are suitable for conducting the ERLTS survey;
- (iv) supervise the survey and ensure that the survey is carried out in accordance with the accepted method statement and the Specification;
- (v) ensure that any damage in the FML identified during the ERLTS survey is repaired and tested according to the requirements of the Specification;
- (vi) ensure that a re-survey is undertaken following any repairs in order to confirm that all repairs are successful and that no additional holes are present that may have previously been masked by neighbouring larger holes.

12.2 The CQA Engineer shall ensure that all elements are documented according to the CQA Programme attached at Appendix C and that the records are presented in the validation report.

13 CONSTRUCTION QUALITY ASSURANCE VALIDATION REPORT

13.1 Following completion of the works, TerraConsult will report fully on the quality control testing and observations undertaken during construction. The report shall be submitted to the NRW within 6 months of the works completion date.

13.2 The Construction Quality Assurance (CQA) Validation Report will constitute a Compliance Document and shall include details of construction quality assurance together with an assessment of the works. As a minimum the CQA Validation Report shall include:

- (i) Description of the works;
- (ii) Daily Records and completed CQA forms;
- (iii) Manufacturer's and Contractor's documentation;
- (iv) Test Reports, both laboratory and field;
- (v) Photographic Records;
- (vi) As-built Drawings as detailed at Appendix C;
- (vii) Details of the treatment for the decommissioning of the boreholes
- (viii) Description of non-conformances and the subsequent remediation (including photos of all repairs made to the GCL and FML systems;
- (ix) Test (laboratory & field) reports (The results of all field and laboratory testing to include any failed tests, details of remedial action taken and re-test;

13.3 The quality assurance programme outlined in this CQA Method statement is not an exhaustive list of procedures to be undertaken during the works but a summary of the minimum requirements and constitutes the basic quality control procedures.

APPENDIX A

ENGINEERING SPECIFICATION

WITHYHEDGE VALLEY CELL CONSTRUCTION WORKS CONSTRUCTION QUALITY ASSURANCE METHOD STATEMENT

APPENDIX A – SPECIFICATION FOR CONSTRUCTION OF CELL LINER AND CELL DRAINAGE

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DOCUMENT REVISION CONTROL SHEET

Report No.	Title
2185R002-002 14 May 2015	Withyhedge Landfill Site Valley Cell Construction Construction Quality Assurance Plan – Appendix A - Specification

Item Reference	Description
2.3.1	Drawing 2185/2/008 – Overflow Details deleted Drawing 2185/2/009 – Cell 13 Leachate Chamber added
2.4.5 – survey 9	Top of stone haunch at 5m chainage; min depth to be 2 x pipe diameter added
2.4.5 – survey 12	Survey added to pick up the as built layout and extent of the sidewall riser pipes
2.4.5 – survey 13	Cell 13 leachate chamber and target pad – as built survey added
2.5.1	Text revised to reflect statements made in letter referenced 2185/L/002 to NRW dated 27 April 2015 regarding the parameters used in the stability risk assessment.
3.2.3	Text added to include for the correct handling and disposal of any asbestos type waste uncovered in the road cut operations.
3.7	Section added to cover for the decommissioning of the existing environmental monitoring boreholes.
4.5.5	Clay liner field trial report is to be sent to NRW but it will not go through the review / acceptance procedure.
4.7.2	Revised text to reflect change in minimum allowable standards for the test results for moisture density testing of the clay liner.
5.7.6	Statement added to include for subgrade approval prior to FML deployment across the GCL surface.
6.6.2	Ditto above – 5.7.6
8.2.9	Text added to include for the fitting of gas tight caps to all pipe ends where open to the atmosphere.
8.3	Section added to include for the leachate extraction sidewall riser pipes.
9.1.1	Change in the minimum allowable depth of the leachate drainage aggregate layer.
9.2.1	Change in the specification for the leachate drainage aggregate to 20/40mm sized material.
Appendix C – CQA Programme Tables	All the above changes have been reflected in the tables included at Appendix C.

DESIGN SPECIFICATION

WITHYHEDGE LANDFILL SITE VALLEY CELL

SPECIFICATION FOR CONSTRUCTION OF CELL LINER AND CELL DRAINAGE

1 INTRODUCTION

- 1.1 In order to allow continuation of landfill operations at Withyhedge Landfill Site, the Valley Cell is to be prepared to accept waste. The required works will comprise the preparation and lining of the Valley Cell.
- 1.2 The Engineer for the works as appointed by Resources Management UK Ltd is Mr Jim Waterworth, Terraconsult Ltd, Bold Business Centre, Bold Lane, Sutton, St Helens. The Engineer has delegated day to day supervision and quality responsibility to the CQA Engineer. This specification reflects this delegation of powers and as such the CQA Engineer is not referred to specifically.
- 1.3 The Contractor, as referenced in this document, will be Resources Management UK Ltd.
- 1.4 The preparation and lining of the Valley Cell will comprise:-
 - Earthworks comprising excavation and filling and compaction to form the cell design formation to the accuracy specified.
 - Earthworks to facilitate surface water management.
 - Deposition of any unsuitable material (contaminated with waste) into the active tipping area
 - Deposition and stockpiling of unsuitable material (non waste) within the site area as directed by the Engineer.
 - Installation of an engineered clay liner / FML composite liner and construction of engineered cell end-bunds, geosynthetic clay liner (GCL) and high density polyethylene (HDPE) flexible membrane liner (FML) to the base and sidewalls.
 - Construction of sub-cell dividing bunds for the control of leachate.
 - Construction of leachate extraction chambers and monitoring points.
 - Construction of cell leachate drainage.

2 GENERAL SPECIFICATION

2.1 Scope of Works

- 2.1.1 The Works will be completed within a strict Construction Quality Assurance (CQA) framework as detailed in the CQA method statement. The Contractor shall take all necessary measures to enable the Engineer to make a successful submission of a validation report to the NRW. The Contractor shall facilitate any requirement in the CQA method statement for the Engineer/Inspector to undertake

tasks which ensure that the highest standards of performance are set and that the lining system is satisfactory in every respect.

2.2 Programme of Works and Constraints

2.2.1 The Works shall be carried out in general accordance with the programme set out below.

- (a) Pump out accumulated water in the Valley Cell and complete site clearance.
- (b) Earthworks (cut and fill) to achieve formation level of Valley Cell.
- (c) Construction of any temporary works (bunds or embankments) on the adjacent slopes to facilitate surface water management.
- (d) Supply and place clay for Valley Cell basal and sidewall lining.
- (e) Grade top surface of Valley Cell basal and sidewall liner.
- (f) Provide and install GCL on basal and lower sidewall engineered clay liner.
- (g) Provide and install FML on engineered clay liner /GCL.
- (h) Provide and install protective geotextile on FML.
- (i) Import and place leachate drainage aggregate on protective geotextile.
- (j) Construct leachate extraction chambers.
- (k) Construct leachate monitoring points.
- (l) Construct sub-cell dividing bunds.
- (m) Grade surface of leachate drainage layer.

2.2.2 The following Site working hours shall be applicable to this contract

0700 to 1900_ Monday to Friday
0700 to 1730_ Sat, Sun and Bank Holiday

2.3 List of Contract Drawings

2.3.1 The Works shall be executed in accordance with the following Drawings:

Drawing No.	Title
2185/2/001	Cell Location
2185/2/002	Cell Formation
2185/2/003	Top of Engineered Clay & Leachate Management Plan
2185/2/004	Waste Placement Phasing
2185/2/005	Long Section
2185/2/006	Leachate Extraction Chambers
2185/2/007	Liner Edge Details
2185/2/008	Leachate Overflow Details – Drawing deleted
2185/2/009	Cell 13 Leachate Chamber

2.3.2 If deemed necessary the Engineer shall issue extra drawings to clarify any part of the Works. The Engineer shall inform Natural Resources Wales of the changes.

2.4 Survey Control and Measurement

- 2.4.1 The Contractor shall be responsible for ensuring that the Works are set out accurately to the Drawings provided and that sufficient surveys are carried out to the satisfaction of the Engineer to prove that the Works have been installed to the Specification. The Contractor shall provide the surveys in Section 2.4.5 below within the timescales specified as a minimum but may be required to carry out other surveys by the Engineer. The Contractor shall state the surveying equipment he plans to use prior to Works commencement and shall state the tolerances to which the system works.
- 2.4.2 Twice the vertical tolerance shall be added to the requirement for layer thicknesses in order to ensure that a minimum of the correct thickness is obtained. All surveys shall be related to the National Grid. The Contractor shall be provided with survey control information for at least two points convenient to the Works. The Contractor shall within one week of the commencement of the Works establish Permanent Ground Markers at locations to be agreed with the Engineer. These Permanent Ground Markers shall be located within the Site boundaries but outside the area of the Works or landfill operations, such that they are not affected by the Works. The co-ordinates and level values shall be established and agreed with the Engineer.
- 2.4.3 The Contractor shall ensure that his operations do not interfere with, or damage, the Permanent Ground Markers. The Contractor shall check the co-ordinates and level values of the Permanent Ground Markers at regular intervals throughout the Contract Period and shall inform the Engineer of any changes which occur.
- 2.4.4 The Contractor shall keep updated schedules and drawings of all Permanent Ground Markers related to the Ordnance Survey National Grid used in setting out and shall make these available to the Engineer when required.
- 2.4.5 The following surveys shall be required:

	Location	Frequency	Timescale	Format
1	Topographical survey prior to earthworks	Points on a 10 metre square grid plus all survey features to accurately represent the site prior to works commencing.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
2	Formation immediately prior to placement of Engineered Clay	Points on a 5 metre square grid plus all valleys, ridge lines and changes in gradient. All shoulders of crests and valleys shall have parallel 1m offset lines on each side surveyed.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
3	Bunds immediately prior to placement of Engineered Clay	Cross sections every 15m along the length of the bund with points every 5 metres along the length of the section (in addition to survey points in 2 above)	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).

	Location	Frequency	Timescale	Format
4	Leachate Extraction Chamber and Monitoring Chamber formation immediately prior to placing Engineered Clay	Two cross sections at right angles, one parallel to the nearest bund with points every 2 metres along the length of the section. All plan points including corners of target pads plus all points as necessary to accurately represent the installation.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
5	Base and sidewalls of cell - Top of Engineered Clay layer after compaction has taken place	Same points on a 5 metre square grid as used in 2 above plus all valleys, ridge lines and changes in gradient. All shoulders of crests and valleys should have parallel 1m offset lines on each side surveyed.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
6	Cell bunds - Top of Engineered Clay layer after compaction has taken place	Same cross sections as survey 3 every 15m along the length of the bund with points every 5 metres along the length of the section. All plan points including corners of target pads plus all points as necessary to accurately represent the installation.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
7	Leachate Sump and monitoring points formation - Top of Engineered Clay layer after compaction has taken place	Same two cross sections at right angles as survey 4, one parallel to the nearest bund with points every 2 metres along the length of the section, top of slab at centre of the chamber is required	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
8	Base and sidewalls of Cell - Base of Drainage Stone Layer	Same points on a 5 metre square grid as used in 5&6 above	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
9	Base and sidewalls of Cell - Top of Drainage Stone Layer	Same points on a 5 metre square grid as used in 8 above. Top of stone haunch at 5m chainage; min depth to be 2 x pipe diameter	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
10	Cell bunds - Top of Drainage Stone Layer	Same cross sections as survey 6 every 15m along the length of the bund with points every 5 metres along the length of the section	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
11	Panel Layout Drawings for Protective Geotextile, GCL and FML	To be agreed with and instructed by the Engineer on Site	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
12	Leachate pipework installation survey	Points taken at 10m chainage points, all pipework including all pipe connections & pipe end points.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).

	Location	Frequency	Timescale	Format
13	Cell 13 leachate chamber and target pad – as built survey record	Four corners of the concrete pad. Points at all toe-lines, crests and corners of drainage aggregate and brick hardcore, position & elevation of chamber	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
14	As required for measurement purposes to evaluate work to be covered up	To be agreed with the Engineer on Site	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).
15	Final “As Installed” survey for measurement purposes and to provide Employer with permanent record of work carried out	To be agreed with the Engineer on Site	Results shall be given to the Engineer within 72 hours of the survey taking place	3 dimensional .dwg file by email to an address agreed with the Engineer, (confirmed receipt must be obtained).

2.4.6 The Contractor shall note that the required timescale for delivery is considered a maximum. No progress shall be allowed on subsequent lining elements until proof is received that the total thickness of the layer being considered is approved.

2.4.7 The Contractor shall complete all surveys in a point upon point manner to achieve an appropriate proving that the specified thickness (layer thickness + 2 x survey tolerance) has been achieved.

2.4.8 The Contractor shall undertake the surveying of the cell construction utilising surveying equipment with a comparable order of accuracy to a Leica GPS system 500.

2.5 Lining Interface Testing (Large scale Shear Box).

2.5.1 The Contractor shall complete interface shear tests comprising large scale shear box tests (to standard ASTM D5321, D6243) on the following interfaces of the lining and drainage system (from the top down).

Protective Geotextile	/	Leachate Drainage Stone
FML	/	Protective Geotextile
Clay	/	GCL
Geocomposite Drainage Layer	/	Formation surface (waste cover soils)

The Contractor shall complete two suites at three different normal pressures. The interface tests shall be completed at three different moisture contents when one interface is a clay material. If clay sources change during the works or multiple sources are proposed further testing shall be completed.

As stated in Item 49 of the SRA (page 9)
"The HDPE (rough) v GCL interface shear strength parameters have been assumed, conservatively, for the interface between the waste and the geosynthetic drain".

The parameters assumed for the design values ie $c' = 0$ and $\phi' = 24.8^\circ$ gave an ODF = 1.44 ie safe. To reduce the ODF to 0 ie just stable would require the design parameters to reduce to $c' = 0$ and $\phi' = 17.8^\circ$. This is an extremely low value for this interface which would never be realised in practice. There is nothing to be gained in carrying out interface shear box tests on this interface.

The Contractor shall give the Engineer the results of all testing along with calculations showing that the testing gives results passing the criteria above. If construction proceeds in advance of receipt of the testing results it shall be entirely at the Contractors risk.

2.6 Services/Installations

- 2.6.1 All known services and installations on the site shall be dealt with – removed or decommissioned, as appropriate before the commencement of the lining works. The Contractor shall note all indicated locations and carefully locate and identify the precise locations of any live services before working in their vicinity.
- 2.6.2 The Contractor shall decommission the groundwater monitoring boreholes BH21, BH22 and BH23, located within the basal area of the proposed Valley Cell. The decommissioning shall comprise infilling of the borehole installation with bentonite slurry from the bottom up by use of a tremmie bar or other similar approved technique. The borehole casing and headworks shall be removed and disposed to tip. The borehole location shall then be over excavated by 2m and infilled with engineered clay material to the satisfaction of the Engineer.

2.7 Protective Clothing and Health Precautions for Workers

- 2.7.1 The Contractor shall provide appropriate PPE for their staff which as a minimum should include the following articles and shall be responsible for ensuring that all personnel comply with their correct use:
- Steel-toed shoes or rain boots with a steel mid-sole.
 - Safety hard hats
 - High Visibility waistcoats/coats. Highway Class 3 to EN471 (long sleeved)

2.8 Safety

- 2.8.1 The Contractor shall be appointed as the Principal Contractor under the CDM Regulations 2007 and or CDM Regulations 2015 for the Works.
- 2.8.2 The Principal Contractor shall ensure that staff, visitors and sub-contractors, Site operatives and other persons authorised to be on Site are aware of and comply with the requirements of the construction phase plan and requirements of the CDM Regulations. The Contractor acting as the Principal Contractor under the CDM Regulations shall be responsible for ensuring relevant data is added to the Health and Safety File, throughout the duration of the Works and returning it, fully updated, to the CDM Coordinator when the Works are substantially complete.

2.8.3 The Engineer shall meet the Contractor before and throughout the duration of the Works, to make sure that the Contractor and his sub-contractors are:

- i) complying with their obligations in respect of statutory requirements;
- ii) implementing safety procedures of standard not less than those of the Employer;
- iii) aware of the foreseeable hazards of the Works which may affect the safety of their employees, the employers and Engineer's employees and members of the public and have incorporated appropriate safety procedures in their method of working.

2.8.4 The Contractor is responsible for providing any sub-contractor with such information.

2.8.5 The Contractor must inform the Engineer of any specific hazards which may arise from his proposed methods of working.

2.8.6 The Contractor shall provide the Contract with a Safety Officer.

2.8.7 The Safety Officer shall be responsible for ensuring that all works comply with the Contractor's Safety Policy, together with the relevant health and safety guidelines.

2.9 Surface Water Control

2.9.1 The Contractor shall ensure that all areas of the works remain free from surplus water impoundment, by providing the Contract with appropriate pumps and ancillary equipment. Casual standing water shall be pumped to an appropriate discharge point.

2.9.2 The Contractor shall provide, operate and maintain sufficient pumping capacity to ensure that surface water collection within the Valley Cell area does not adversely affect any of the works.

2.9.3 The Contractor shall undertake adequate temporary works to protect the leading edges of the lining system. Damage caused to the lining system caused by a lack of protection shall be repaired.

2.10 Contract Organisation/Definition of Site Area

2.10.1 The Contract shall be organised as follows:

Employer	Resources Management UK Ltd.
Design Engineer	TerraConsult Ltd
Engineer	TerraConsult Ltd
CQA Engineer	TerraConsult Ltd
Contractor	Resources Management UK Ltd

2.10.2 The Contractor shall provide a full-time suitably qualified Engineer / Site Manager with adequate experience of similar works who shall control all aspects

of the Contractor's operations on site for the duration of the Contract and shall liaise on a daily basis with the Engineer's Representative on site.

2.10.3 Progress meetings shall be held fortnightly, or such other frequency as agreed. The meetings shall be attended by the Employer, Engineer, Contractor and relevant subcontractors, if appropriate, to discuss both formally and informally the progress of the Works so as to ensure good communications and the smooth running of the Contract. These meeting shall be minuted by the Engineer and actions allocated accordingly.

3 EXCAVATION AND BACKFILLING

Definition

The following definitions shall apply to the Contract wherever reference is made to the defined material.

“Suitable material” – shall comprise material which is not unsuitable material and is in accordance with the Contract for use in the Works and is approved by the Engineer.

“Unsuitable material” – shall mean material other than suitable materials and shall include:

- Peat, material from swamps, marshes and bogs.
- Logs, stumps and perishable material.
- Material in a frozen condition or susceptible to spontaneous combustion.
- Building rubble or non-ferrous material.
- Any industrial, commercial or domestic waste.
- Any material greater than two-thirds of the compacted layer thickness.
- Fill material with a high moisture content which when compacted does not provide a firm foundation sufficient to permit the movement of vehicles without causing excessive rutting
- Clay liner material having a moisture content greater than the maximum or less than the minimum permitted for such material unless otherwise approved by the Engineer.
- Clay of liquid limit exceeding 90% and/or plasticity index less than 10% or exceeding 65%.
- Unsuitable Materials of Class (viii) if otherwise suitable shall be classified as suitable when wetted or dried sufficiently as appropriate.

“Rock” – shall mean those geological strata that cannot be removed from an excavation up to 4m deep with a Caterpillar 345 or equivalent excavator in good working order. As the main excavation is within mudstone the word Rock shall mean “hard dig mudstone”.

3.1 Preparatory Works

- 3.1.1 The Contractor shall dispose of any uncontaminated water accumulated in the Valley Cell by pumping it to an appropriate discharge point.

3.2 Formation Level - General

- 3.2.1 The existing topography of the Valley Cell is shown on Drawing 2185/2/002 & 003.

After undertaking any requisite enabling works (site clearance) the Contractor shall prepare the formation by cut and fill activities. The cell formation level shall be prepared by the placement and compaction of excavated clean on-site derived materials. Compaction shall be in accordance with Highway Agency’s Specification for Highway Works, Series 600.

If filling with site won / imported cohesive material becomes necessary the formation level shall be prepared such that it achieves a minimum shear strength as set out in Table 3.5 below. Where the surface is cohesive material the Engineer shall check the finished formation level on an approx. 10 metre square grid to ensure that the surface of the formation has achieved the required shear strength. Before any filling takes place upon cohesive material the Contractor and the Engineer shall jointly inspect every surface to receive fill and identify any soft or open textured areas.

- 3.2.2 All soft areas shall be excavated and replaced with fill in accordance with section 3.5, below or similar approved by the Engineer which shall be placed in accordance with the Highways Agency Specification for Highway Works, Series 600 in layers. Each layer shall be compacted with approved plant to the satisfaction of the Engineer. The material excavated shall be removed to a location on Site agreed with Resources Management UK Ltd and Engineer

- 3.2.3 It is understood that asbestos contaminated material has been placed onto the site haul road forming the base of the valley cell and although at levels below hazardous waste thresholds, any excavated materials requiring disposal will be handled and landfilled within the main landfill body in accordance with the site rules and procedures.

- 3.2.4 The Contractor shall proof roll all formation basal and sidewall surfaces immediately before any Engineered Clay is placed. Where the Engineer deems that the surface is not sufficiently competent it shall be treated as in Section 3.2.2 above.

- 3.2.5 With the exception of excavation for the leachate extraction chambers or excavation of flaws as described above, the Contractor shall not excavate below the formation level indicated in Drawing 2185/2/002.

- 3.2.6 The Contractor shall organise haul roads such that the formation level of the Phase receives minimum traffic and suffers no rutting or other damage.

3.3 Formation - Excavation

- 3.3.1 Where excavation is required to prepare the formation or enabling works to the Valley Cell site the Contractor shall selectively excavate material to the formation level indicated in Drawing 2185/2/002. All finished excavated faces shall be no steeper than 1 (v) to 2 (h). The tolerance for achieving design level is +0mm - 50mm.

- 3.3.2 The Contractor shall selectively excavate the material available to produce:-

- a) Material suitable for Engineering, to include all Contractor processing,
- b) Unsuitable Material as defined in the Specification for Highway Works, Series 600, Section 601, unacceptable material classification U.

- 3.3.3 The Contractor shall excavate a depression in the prepared formation level for the leachate extraction chamber and the leachate monitoring chamber.

3.4 Disposal of Excavated Material

- 3.4.1 The Contractor shall remove all material excavated and dispose at the most appropriate location, on site, either:-

- to the formation filling operation or;
- Stockpiled within the site footprint;
- to the active tip.

- 3.4.2 The Contractor shall manage his tipping operations such that the material in storage locations does not impound water.

- 3.4.3 The Contractor shall ensure that no slope on the storage areas is greater than 1 in 2.

3.5 Engineered Fill – Backfill Operations

- 3.5.1 Where filling is required to prepare the formation level the Contractor shall raise existing levels to cell formation levels by the placement and compaction in layers of fill either imported onto the site by the Contractor or available fill won on site.

The fill material shall be won from the excavation areas within the Valley Cell. The fill shall be classified in accordance with the categories in Series 600 of the Highways Agency Specification for Highways Works and the specified compactive effort applied.

Class 1 and Class 2 backfill materials, as defined by Series 600 of the Highways Agency Specification for Highways Works shall be compacted in separate layers and shall not be mixed in the same layer. If mixing occurs within the same layer, the mixed materials shall be excavated and disposed of, on-site, at a location agreed with the Engineer.

The placement and compaction of the engineered backfill shall be carried out by method specification using methods and equipment in general accordance with Table 6/4 of the Highway Agency's Specification for Highway Works. The Contractor and the Engineer shall develop a detailed method statement for the construction of the engineered backfill. Compaction shall be in accordance with Appendix 6/1 of the Highway Agency's Specification for Highway Works.

Material shall be laid as far as practicable in horizontal layers with equal thickness to minimise differential settlement. The design tolerance to achieve formation shall be +0mm -50mm.

As far as practicable the engineered backfill shall be brought up at a uniform rate so that the full length of the specific section of backfill reaches finished level at the same time.

Each layer of fill and the final surface shall be placed in accordance with the Highway Agency's Specification for Highway Works. The Engineer shall observe the placement of the Class 1A material and record the compactive effort applied to each layer.

Where cohesive material is used it shall be placed so that the minimum shear strength in Table 3.5 below is achieved as measured by the Engineer with a hand shear vane. The Engineer shall also observe the placement of the Class 2 material and record the applied method.

3.5.2 Fill shall be available from the following sources:

- the excavation operation in Section 3.3
- suitable, selected materials stockpiled on site from previous earthworks projects
- suitable, selected materials from the quarry area

Table 3.5 Engineered Fill Testing Requirements

Property	Test Method	Units	Testing Frequency	Required Value
Shear Strength (in cohesive material)	Hand Shear Vane in accordance with Manufacturers Instructions	kPa	10m grid on finished formation surface and intermediate fill layers in cohesive material	≥45
Moisture content (in cohesive material)	ASTM D4643 – microwave method	%	Refer to Appendix C	≥ Plasticity Index
Compaction	Visual observation of layer thickness and compactive effort	N/A	Monitor the Works – to follow the agreed method statement	To satisfaction of Engineer

Tests shall be undertaken at the frequencies detailed at Appendix C, CQA Programme Tables.

3.6 Engineered Fill – Remediation

3.6.1 Acceptability of the backfilled materials shall be to the satisfaction of the Engineer. Should the compacted cohesive fill not meet the hand shear vane (HSV) criterion or should the compacted Class 1 fill material not have been compacted in accordance with this Specification, an area within a 12.5m radius of the test location shall be removed and subsequently re-compacted with suitable compaction plant in accordance with this Specification. Any remedial works carried out to the formation shall be carried out in full accordance with this Specification until a successful result has been achieved and to the satisfaction of the Engineer.

3.7 Decommissioning of Existing Cell 1 South Leachate Riser Pipe

3.7.1 The existing upslope riser located at the southern edge of Cell S1, within Cell 1 South is to be decommissioned. Waste shall be excavated to uncover at least 2m length of the pipe below the existing sidewall crest line. The pipe shall be cut back 1.5m below the existing sidewall crest line and a permanent end cap shall be butt fused or electrofused onto the existing pipe end. Waste shall be replaced.

3.8 Decommissioning of Boreholes BH21, BH22 and BH23

3.8.1 The existing boreholes BH21, BH22 and BH23 will be decommissioned in accordance with this document. It has been agreed with NRW that the boreholes will not need to be replaced due to effective monitoring provided by other, existing boreholes.

3.8.2 One of the following procedures shall be followed by the drilling team, under the supervision of the CQA Inspector for the decommissioning of the boreholes referenced above. The procedures are based on the options given for borehole decommissioning in 'Good practice for decommissioning redundant boreholes and wells', Environment Agency, October 2012.

EA Guidance Option B

The objective of the procedure is to achieve decommissioning by mimicking the surrounding geology.

- Assess existing ground conditions around the borehole and if not firm then make good by placement of granular fill to enable the works to be completed
- Drill out and remove the existing monitoring installation within the borehole including as much as possible of the bentonite and gravel surround and including the headgear
- Backfill the borehole using 10-20mm limestone to approximate level of top of limestone or depth of 3.5m bgl, whichever is the higher position
- The CQA Engineer will monitor and record the quantity and therefore the volume of gravel used to backfill the borehole
- Backfill borehole with a layer of dry sand approximately 0.5m thick

- Backfill borehole with hydrated bentonite powder or pellets to 0.5m bgl
- Mix and place post-crete between the top of the bentonite seal and ground level as a top seal

EA Guidance Option C

The objective of the procedure is to achieve decommissioning by use of low permeability backfill.

- Assess existing ground conditions around the borehole and if not firm then make good by placement of granular fill to enable the works to be completed
- Drill out and remove the existing monitoring installation within the borehole including as much as possible of the bentonite and gravel surround and including the headgear
- Insert and position a suitable tremie pipe to the base of the borehole and inject a pre-mixed bentonite cement grout using a low pressure grout pump
- Maintain pumping until grout has backfilled the borehole to within 0.5m of ground level; maintain control on the volume of grout injected
- Mix and place post-crete between the top of grout and ground level as a top seal

3.8.3 The most appropriate option shall be agreed between the CQA Engineer and NRW before the decommissioning work commences. Variation to the agreed procedure is to be with prior agreement with the CQA Engineer and will be in accordance with the Environment Agency's 'Good Practice for Decommissioning Redundant Boreholes and Wells'

4 ENGINEERED CLAY LINER (ECL)

4.1 General

4.1.1 The Contractor shall supply and place the clay to a thickness of 0.5m to achieve a permeability of 1×10^{-8} m/s or less of approved clay.

4.1.2 A suitable source of clay liner material shall be identified and a source evaluation report shall be prepared by a suitably qualified Geologist or Engineer for presentation to Natural Resources Wales for each clay source proposed. The requirement for a testing suite will be as follows:

- Permeability : re-moulded : BS1377 : Part 6 : Test 6;
- Natural moisture content : BS1377 : Part 2 : Test 2;
- Moisture content/dry density relationship : BS1377 : Part 4 : Method 3.3/3.4 - 2.5kg Compaction;
- Plasticity Index : BS1377 : Part 2 : Method 5;
- Particle Size Distribution : BS1377 : Part 2 : Methods 9.2 and 9.4;
- Particle Density : BS1377 : Part 2 : Method 8;
- Organic content : BS1377 : Part 3 : Method 3; (if appropriate only)
- Multistage quick undrained shear strength : BS1377 : Part 7 : Method 7.
- the source testing shall be undertaken at a frequency in accordance with Environment Agency guidance LFE4, Table 5.

- 4.1.3 The Engineer will require to inspect the clay in situ before approval will be given. Approval must be obtained before the clay is used on site
- 4.1.4 The Contractor shall install the clay over the base and sidewall areas of the Cell as shown on Drawing 2185/2/003 and in accordance with the detail in Drawings 2185/2/006 and 2185/2/007. The clay shall be compacted to a minimum thickness as set out in Table 4.1 below increased by twice the vertical tolerance of the surveying equipment used by the Contractor to determine the thickness. The Contractor shall condition the clay by the provision and application of sufficient water and / or working the clay to ensure that the moisture content of the clay is satisfactory to achieve the required compaction whilst maintaining sufficient shear strength. The thickness shall be measured (point upon point) normal to the surface after compaction. The tolerance for the minimum depth of the installed layer shall be within the range + 50 mm to - 0 mm. If the results of the surveying indicate that the liner does not comply with the Drawings the Contractor shall ensure that additional clay is laid and compacted onto any areas proved not to be thick enough in accordance with the requirements of the Contract.

Table 4.1 Requirements for Engineered Clay Thickness

Application	ECL Thickness (mm)	Total Thickness (mm)
Basal Liner	500	500mm + 2x survey tolerance
Sidewall Liner (measured perpendicular to surface)	500	500mm + 2x survey tolerance

4.2 Formation/Subgrade Surface

- 4.2.1 The Contractor shall ensure that the surface is free of:
- a) Vegetation and putrescible material;
 - b) Objects that would protrude into the engineered clay liner by more than 25 mm;
 - c) Soft spots and hollow areas.
- 4.2.2 Where necessary, soft areas of subgrade shall be removed and replaced with suitable material compacted as described in section 3.5 above. In addition if precipitation has caused deterioration of the surface of the subgrade the contractor shall remove and replace any area deemed unsuitable by the Engineer before the Engineered Clay Liner is laid.
- 4.2.3 The Contractor shall survey the subgrade in accordance with Section 2.4 of this Specification.
- 4.2.4 The Contractor shall inform the Engineer when areas of subgrade are ready for inspection. The area ready for inspection shall be clearly delineated using a method agreed with the Engineer. Engineered Clay Liner shall not be constructed on areas of subgrade which have not been approved in writing by the Engineer.

The approval shall be recorded on a subgrade release form. The specification for the performance of the ECL subgrade is described at section 3.

4.3 Method of Working

- 4.3.1 The method to be applied for the placement and compaction of the ECL shall be based on the plant and equipment to be used by the Contractor and from the results of the trial liner. The trial liner report shall form the defined method for the working of the clay liner.

4.4 Engineered Clay Liner Specification

- 4.4.1 Clay shall be used in the construction of the landfill cell liner such that the clay placed achieves the desired seal at the base and side slopes of the landfill. The Contractor shall ensure that Engineered Clay Liner meets the following specification:

- a) The permeability of the clay liner shall not be greater than 1×10^{-8} m/s.
- b) The material shall have a minimum fines content (defined as particles finer than 0.063 mm) of more than or equal to 20%.
- c) The material shall have a minimum clay content (defined as particles finer than 0.002 mm) of more than or equal to 8%.
- d) The material shall have a maximum gravel content (defined as particles coarser than 5mm) of less than or equal to 30%.
- e) The liquid limit shall be less than or equal to 90%.
- f) The plasticity index shall be not less than or equal to 10% and not greater than or equal to 65%.
- g) The Engineered Clay Liner thickness shall be as shown in Table 4.1 plus twice the survey tolerance, measured perpendicular to its surface.
- h) The maximum stone size shall not exceed 125 mm.
- i) The clay material shall be compacted such that the material contains no more than 5% of air voids by volume. The minimum moisture content shall be equal to the plastic limit; the maximum moisture content parameters shall be confirmed by the Engineer after the trial pad results are known.
- j) The shear strength of the ECL shall be a minimum of 50 kPa.

The Engineer shall monitor clay during placement and the Contractor shall remove any material deemed unsuitable to a stockpile specified by the Engineer.

4.5 Engineered Clay Liner Trial

- 4.5.1 The Contractor shall undertake a field trial to prove that the proposed clay liner construction methodology will achieve the required specification. The field trial is to be undertaken using the same plant and techniques which are to be used in placing the liner. The trial liner shall be undertaken on the base and sidewall of the cell.
- 4.5.2 The contractor shall complete the trial utilising the clay proposed as the main lining clay. The moisture content of the clay used in the trial shall be that operational on the test date but it should be within the range already decided by

the source evaluation testing. If it is not then it must be adjusted to fall within the acceptable range.

- 4.5.3 As directed by the Engineer the minimum test area shall be approximately 3 times the width of the compaction plant to allow for side effects. The minimum length of the trial area shall be approximately 5 times the combined length of the compaction roller and towing plant (if present) to allow for variation in thickness at the ends and to ensure enough area is available to be representative of a large section of the clay liner and to allow sufficient spread of test and sampling locations. The trial liner shall consist of 3 lifts. On completion of its construction the trial liner shall be destructively tested by dismantling as directed by the Engineer
- 4.5.4 The area of trial clay liner shall be subdivided into four and within each quadrant, the Engineer will test the Trial Liner in accordance with the CQA Method statement. Where the results show that methodology and plant used to place the trial clay liner achieve the required specification, the Engineer will issue written approval and works may proceed with placement of the clay liner. If the results of the field trial prove unsuccessful the Contractor shall revise the liner placement methodology and compaction plant requirements and carry out a further trial to assess the revisions. This process shall continue until the Engineer is satisfied that the proposed plant and methodology will produce satisfactory results. The Contractor shall remove all failed trial liner material from the subgrade of the cell.
- 4.5.5 On completion of the field trial the Engineer shall forward the results to the NRW as part of a field trial report.

4.6 Engineered Clay Liner Construction

- 4.6.1 The Contractor shall construct the Engineered Clay Liner using the plant and methodology defined in the trial liner report.
- 4.6.2 The Contractor shall ensure that:
- a) The clay is placed in separate layers such that, when compacted each layer is no greater than a nominal 250 mm thick;
 - b) The surface of each layer is scarified to a nominal depth of 25 mm prior to the placement of any subsequent layer of Engineered Clay Liner;
- 4.6.3 The Contractor shall inform the Engineer when areas of Engineered Clay Liner layers have been completed prior to scarifying. Where the results show that Engineered Clay Liner achieves the required specification the Engineer will issue written approval and works may proceed with scarifying and placement of subsequent layers.
- 4.6.4 If the results of the compliance test results show that the layer does not meet the Specification then the non-conformance conditions specified in Section 4.7 below shall apply.

4.6.5 The Contractor shall remove clay deemed to be unsuitable to a stockpile specified by the Engineer.

4.6.6 The Contractor shall ensure that the top of the Engineered Clay Liner is surveyed in accordance with Section 2.4 of this Specification. The survey previously carried out on the prepared subgrade shall be used to establish liner thickness.

If the results of the surveying indicate that the liner does not comply with the design drawings. The Contractor shall lay additional clay in accordance with Section 4.4 above and compact it in accordance with the requirements of the methods established during the liner trials onto any areas proved not to be thick enough. All layers of additional clay will be tested in order to test compliance with Section 4.4 above.

4.6.7 Clay Perforations

All perforations made in the liner for testing and measurement purposes shall be backfilled with bentonite or clay material approved by the Engineer and shall be compacted in place. This procedure shall apply to but not be limited to:

- a) core cutter sample locations
- b) permeability sample locations
- c) nuclear density meter test hole locations
- d) disturbed bulk sample locations

4.7 Compliance Testing

4.7.1 The Contractor shall inform the Engineer when an area of clay liner or an area of any intermediate layer has been completed. The Engineer will then carry out a regime of compliance testing to ensure that the plant used and techniques adopted have produced a liner which meets the requirements of the specification. Subsequent layers of clay shall not be placed until the Engineer has confirmed in writing that the previous layer has passed the compliance testing.

4.7.2 Where the statistical derivation of pass fail criteria is to be used (as detailed on page 36 of the Environment Agency's LFE4 – "Earthworks in Landfill Engineering" the value of "A" for the pass/fail criteria shall be a minimum of 95% of test results to indicate $\leq 5\%$ air voids, in accordance with the more stringent pass/fail criteria applicable to major aquifers.

4.7.3 Non-conformance

At locations where the results of the field testing indicate dry densities below the requirements of the specification an area of non-conformance will be recorded. The extent of the non conforming area will be determined by the Engineer as the area inside the surrounding conforming test locations. Depending upon the need to progress the Contract the Engineer may at his discretion carry out further density determinations to more closely define the area of non conformance.

4.7.4 If the results of the compliance testing indicate that the acceptance criteria have not been met then one or more of the following rectification procedures shall be adopted:

- a) Adjustment of the clay moisture content by addition of water or by scarifying and drying until the required moisture content is obtained, followed by additional compactive effort applied as necessary such that the results of subsequent testing comply with the acceptance criteria; or
- b) Make good by removing the material either to tip or elsewhere as determined by the Engineer until it is in a suitable condition for re-use and replacing it with suitable material; or
- c) Cease work on the material until its physical condition is such that it can again be compacted in accordance with the stated procedure so as to comply with the acceptance criteria.

5 GEOSYNTHETIC CLAY LINER (GCL)

5.1 General Description

5.1.1 The Contractor shall provide and lay a Geosynthetic Clay Liner (GCL) in contact with the approved surface of the Engineered Clay Layer (ECL), and in accordance with the detail shown on the Drawings. A suitably qualified and experienced Contractor shall install the GCL.

5.2 GCL Material

The GCL shall comprise of a layer of natural sodium bentonite clay encapsulated between a woven and non-woven geotextile, needle-punched together, and shall meet the requirements in Table 5.2.

Table 5.2 – GCL Requirements

PARAMETER	TEST METHOD	REQUIREMENT
GCL SHEET		
Thickness	ASTM D 5199/EN ISO 14196	6mm
Mass per unit area of GCL reported at natural moisture content 15%	EN ISO 14196	>5,000g/m ²
CBR puncture resistance of GCL	BS 6906 / EN 12236	>1100 N
Peel Strength	ASTM D4632	>36 N/10cm (min.)
Tensile Strength (md)	EN ISO 10319/ASTM D4595	10.5kN/m
Index flux	DIN 18130 / ASTM D5887	5 x 10 ⁻⁹ m ³ /m ² /s (max)
Hydraulic Conductivity	ASTM D5887 (distilled water @ 35 kPa confining stress)	1 x 10 ⁻¹¹ m/s
BENTONITE LAYER		
Mass per unit area of bentonite component reported at natural moisture content 15%	EN ISO 14196	4,670g/m ² (min.)
Montmorillonite Content	VDG P69/XRD	70% (min.)
Cation Exchange Capacity	Methylene Blue (EA Guidance on GCBs App. A)	300 mg/g (min)
Moisture content of bentonite	DIN 18121 /ASTM D4643	15 % (max)
PARAMETER	TEST METHOD	REQUIREMENT
Free swell	ASTM D5890	24 ml / 2g (min.)
Water absorption	ASTM D8591	600% (min.)
Fluid loss	ASTM D5891	18 ml in 30 min. (max.)
GEOTEXTILES		
Mass per unit area of non-woven geotextile	EN 965	200 g/m ² (min.)
Mass per unit area of woven geotextile	EN 965	100 g/m ² (min.)

5.2.2 The interface shear strength of the Geosynthetic Clay Layer and the Engineered Clay Layer shall be confirmed via direct laboratory testing.

5.2.3 The geotextile material shall be manufactured from inert polymeric materials which retain their structure during handling, placement and long term service, have satisfactory resistance to acid and alkali action, are resistant to attack by micro-organisms and insects and are ultra violet light resistant.

5.2.4 The GCL shall be interwoven by mechanical bonding of the needle punching process. The manufacturer shall verify that the geotextile component has been inspected continuously for the presence of broken needles and certify it is needle free.

5.2.5 The Contractor shall provide the Engineer with full details for his approval of the proposed GCL to be used prior to any being delivery to site. The Contractor shall also provide the Engineer with a copy the manufacturer's recommendations and installation instructions.

5.3 Delivery, Handling and Storage

5.3.1 The GCL shall be delivered to site in the form of rolls, prepared, packed and loaded in a manner, so as to prevent any damage during handling. The GCL shall be delivered to site in packaging which will protect the rolls from degradation by ultra violet light. The GCL shall be kept in the wrappings provided by the manufacturer until required for use in the Works.

5.3.2 Each roll of GCL delivered shall be clearly labelled with the name of the manufacturer, product name and type, batch and roll number, roll length, width and roll weight and date of manufacture.

5.3.3 On delivery to site, rolls will be off-loaded to storage using a crane or suitable available construction equipment. Each roll should be equipped with canvas slings to facilitate unloading.

5.3.4 The Contractor shall mark any damaged or defective rolls and then segregate them for further investigation, as necessary.

5.3.5 The rolls shall be stacked not more than three high and stored in accordance with the manufacturer's recommendations in a storage area which shall be clean, firm, dry, and free of rocks or other detritus, and located so as to preclude damage from impact or puncture by working plant, vandals or such like. The location of the storage area shall be agreed with the Engineer. In order to protect the GCL rolls from the weather, all rolls shall be covered by a waterproof sheet.

5.4 Manufacturer's Quality Control

5.4.1 The Contractor shall provide the Engineer with a copy of the manufacturer's quality control documentation and certificates accompanying each roll of GCL on the day it is delivered to site or a copy of the manufacturers CE mark test certificate where applicable. The quality control documentation shall include the following information for each batch of material delivered to site:-

- The origin (suppliers name and location of material source) and identification of the bentonite used for production of the GCL;
- Copies of dated Quality Control information issued by the bentonite supplier;
- Results of Quality Control tests conducted by the GCL manufacturer to verify that the bentonite supplied meets the GCL manufacturer's specifications;

- Copies of dated Quality Control information provided by the GCL manufacturer, and;
- Quality Control certificates, signed by a representative party employed by the manufacturer. Each Quality Control certificate shall include roll identification numbers, testing procedures and results of Quality Control tests.

5.5 Conformance Testing

- 5.5.1 The Contractor shall provide access for the Engineer to recover samples from the GCL rolls for conformance testing in accordance with the requirements of the QA Plan. The samples will be 1m long across the full width of the roll. More than one sample may be recovered from each roll. The Engineer will provide a copy of the results of the testing to the Contractor on request, but this shall not relieve the Contractor from any of his obligations under the Contract.

5.6 Surface Preparation Prior to GCL Deployment

- 5.6.1 The subgrade shall comprise the upper surface of the ECL, which shall be prepared in accordance with this Specification and the agreed methods and compaction parameters derived from the results of the trial liner.
- 5.6.2 The Contractor shall ensure that the subgrade surface is firm, smooth, free of foreign matter, free of cracking, free of sharp objects, free of protrusions raised more than 10mm above the surface which could damage the liner and free of abrupt changes in the gradient which could be bridged by the GCL. All the foregoing to be to the satisfaction of the Engineer.
- 5.6.3 The area of subgrade accepted by the Engineer for laying shall be delineated on a daily basis with an agreed location system. Any areas deemed as unsatisfactory by the Engineer and any necessary remedial work required shall be notified to the Contractor for action. The Engineer shall record his agreement that areas of subgrade are satisfactory on a subgrade release form. Should the Contractor delay placement of the GCL over the approved surface, and as a result the condition of the surface deteriorates, approval may be withdrawn until the surface has been remediated to meet the requirements of the Specification.
- 5.6.4 Areas of the subgrade which have been deemed unsuitable shall, after remediation, be re-inspected by the Engineer to ensure they are acceptable. The GCL shall only be laid on areas of subgrade approved in writing by the Engineer on the day of installation.
- 5.6.5 Prior to any GCL installation, the Engineer shall inspect the receiving surface to verify that it is fully in accordance with this specification, and that no stones, excessive dust or moisture could be entrapped beneath the GCL. No GCL shall be installed on an area until the Engineer has granted approval.

5.7 GCL Deployment

- 5.7.1 The Contractor shall submit an installation plan and method statement to the Engineer for approval before commencing installation. The plan shall illustrate the location of each panel and shall be developed with the principal objectives of minimising the number of panels. The Plan shall not be amended without the prior approval of the Engineer.
- 5.7.2 Each GCL panel shall be given a unique reference number consistent with the installation plan. Roll numbers shall not be used as a panel identification code. The panel identification code shall be used for all site records pertaining to that panel.
- 5.7.3 The GCL shall be installed with the woven geotextile in direct contact with the approved surface unless otherwise stated in the manufacturer's recommendation for installation. All GCL panels shall be arranged so that seams are oriented parallel to the line of maximum slope, whenever practicable. In corners and odd-shaped geometric locations, the panel layout shall be such that the number of seams is kept to a minimum.
- 5.7.4 The Contractor shall ensure that:-
- equipment, plant and tools used shall not damage the GCL by handling, trafficking, leakage of hydrocarbons or by other means;
 - personnel working on the GCL shall not smoke, wear shoes likely to cause damage, or otherwise engage in any activity that could damage the GCL;
 - the method of placement shall be in such a manner as to minimise the risk of damage or disturbance to the GCL and underlying layers;
 - the GCL shall be in continuous contact with the surface on which it is placed without stretching or bridging over humps and hollows;
 - during placement of the GCL, care shall be taken not to entrap beneath any panel, any stones, excessive dust or moisture that could damage it;
 - the GCL material shall be cut in a manner recommended by the manufacturer with due care to prevent damage to any adjacent liner system component during cutting;
 - the method of deployment shall minimise wrinkles;
 - only GCL to be used on the same working day shall be removed from the store;
 - deployment and jointing shall not take place during periods of precipitation or in the presence of excessive moisture (fog, rain, snow, or heavy dew) that may cause rapid hydration of or damage to the GCL or in the presence of excessive winds;
 - GCL deployment shall not be undertaken in areas of ponded water or in such a way that increases the potential for hydration of the material prior to completion of construction of the overlying lining system;
 - direct contact with the GCL is minimised, and;
 - construction plant shall not traverse over any area of GCL until sufficient depth of cover has been placed over it in accordance with the Specification.
 - The Contractor shall ensure that the edges of the lining system are protected against water ingress which might appear between the FML and GCL (see detail on Drawing 2185/2/007).

- 5.7.5 Exposed panels of GCL shall be protected against wind load with sandbags or similar that will not damage the GCL. On steep embankments, suspension of sandbags by ropes may be required. This protection shall remain in place until the overlying layers are placed over the panel. Exposed edges of the GCL shall be similarly weighted down at the end of each working day
- 5.7.6 All GCL panels placed in any one day shall be covered where practicable with the installed FML on the same day. Any areas of the GCL remaining exposed shall be covered with FML off-cuts or plastic sheeting and adequately weighted down as protection from precipitation or wind disturbance. Prior to the further deployment of the GCL, any excessively hydrated material shall either be covered with new material or removed and replaced as directed by the Engineer. **The Engineer shall record approval of the subgrade in writing using an appropriate record. Example CQA records are attached at Appendix G.**
- 5.7.7 The GCL shall be finished and anchored at its edges in accordance with Drawing 2185/2/007. Any anchor trench shall be excavated and approved by the Engineer prior to GCL placement. No loose soil or standing water shall be allowed at the bottom of the trench and no sharp corners or protrusions shall exist anywhere within the trench
- 5.7.8 The Contractor shall ensure that the GCL is not damaged by premature hydration before the required confining loading is applied.

5.8 GCL Overlaps

- 5.8.1 All GCL panels shall be overlapped by a minimum of 250mm. End-of-roll overlap shall be a minimum of 500mm. The edges of the panels shall be adjusted to smooth out any wrinkles, creases or “fishmouths” in order to maximise contact with the underlying panel. Wrinkles, creases or “fishmouths” that cannot be smoothed shall be treated as defects and will be repaired by the Contractor in accordance with this Specification.
- 5.8.2 On the side slopes the FML panels shall be installed parallel to the direction of slope (i.e. downslope) and without any horizontal seams on the slope. Throughout the installation up-slope panels will overlap down-slope panels, in order that flow is over the seam and not into the seam. After panels are placed the Contractor will establish proper overlap orientation and pull back the edge of the panel to expose the overlap zone. The Contractor will remove any soil or other deleterious material present in the overlap zone prior to sealing.
- 5.8.3 The Contractor shall either supply GCL with its edges impregnated with bentonite at the factory or apply accessory bentonite in the overlap zone at a minimum rate of 0.5 kg/lin. m to form of a continuous bead or fillet of bentonite powder or paste to seal the overlap. Accessory bentonite shall be applied at panel ends and where the GCL sheet has been cut to fit the agreed panel layout.

5.9 Damage, Defects and Repairs

- 5.9.1 The Contractor shall repair any visible damage or defects in the GCL by installing a patch of the same GCL, which has an overlap of at least 300mm around the damaged area. The patch will be secured with bentonite paste approved by the manufacturer or in another such manner as required by the manufacturer's recommendations and installation instruction to create an air and water tight seal.
- 5.9.2 The Engineer may direct the whole of a panel to be replaced depending upon the nature and extent of the damage or defect

6 HIGH DENSITY POLYETHYLENE FLEXIBLE MEMBRANE LINER (HDPE FML)

6.1 General Description

- 6.1.1 The Contractor shall provide and install a double textured 2.0mm thick HDPE Flexible Membrane Liner (FML) on the base of the cell, extending to the crest of the perimeter bunds. The Contractor shall employ a suitably qualified and experienced specialist FML Contractor to install the FML.

6.2 Preliminaries

- 6.2.1 The Contractor shall provide an FML method statement to the Engineer for review and approval prior to the commencement of FML installation.
- 6.2.2 Prior to any FML installation, the Contractor shall submit to the Engineer a schematic plan showing the proposed layout of FML panel installation for agreement. The panel layout shall seek to minimise the number of seam welds required. The plan shall detail the proposed location of any extrusion seams.
- 6.2.3 Prior to any FML installation a representative of the FML Contractor shall attend a pre-start meeting to be held on site to discuss and agree the programme for the work and any other matters arising.

6.3 Material Specification

- 6.3.1 All FML material shall be manufactured by an extrusion process using pure (non-recycled) resin, entirely free of plasticizer or other filler materials and without prefabrication. The FML shall fully comply with the requirements of either Table 1b or 2b of the Geosynthetic Research Institute (GRI) Test Method GM13 Standard Specification (see Appendix B).
- 6.3.2 The Contractor shall submit to the Engineer a copy of the manufacturer's quality control documentation for each roll of FML delivered to site. The documentation shall be provided prior to installation of any material. The Engineer shall review the data to verify that it meets the requirements of the FML specification detailed at Appendix B.

6.3.3 The Contractor shall provide the Engineer with the following documentation as a minimum, for each FML roll, unless otherwise agreed with the Engineer:

- Name of manufacturer
- Place of manufacture
- Date of manufacture
- Product identification
- Thickness of the material
- Length and width of roll
- Directions to unroll the material
- Lot number/Resin batch number
- Roll Test Data
- Environmental Stress Cracking Value
- Oxidative Induction Time Value
- Tear resistance

6.3.4 If the date of manufacture of any roll is more than 1 year prior to delivery to site then the manufacturer and or supplier is to provide a certified provenance for the roll detailing the location at which the roll has been stored and the conditions it was stored under.

6.4 Delivery, Storage and Handling

6.4.1 The FML material shall be delivered, stored and handled strictly in accordance with the manufacturer's instructions. The handling equipment and storage method employed shall ensure no damage to the FML. Each roll delivered to site shall be identified with the name of the manufacturer, the product name and type, the thickness, the batch number, the length and the date of manufacture. Any protective coatings shall not be removed until the material is ready to be incorporated into the works.

6.4.2 The FML shall be stored at a location to be agreed on site and shall not be stacked more than 2 rolls high. No materials shall be placed on top of the FML. The storage area shall be firm, clean and rolled flat to avoid damage to the FML. The Contractor shall provide adequate and acceptable measures for protecting the materials at all stages of the work from all sources of potential damage, including adverse weather conditions until completion of the Works.

6.4.3 Upon delivery the Engineer shall oversee the unloading and storage of the material and shall visually examine all rolls for damage. Any damage shall be marked for further investigation as necessary. The Engineer shall record the relevant reference numbers of each roll.

6.5 Conformance Testing

6.5.1 Samples shall be taken from selected rolls of FML as determined by the Engineer at the frequency detailed in Table 6.5, below, and submitted for conformance testing at an independent laboratory with UKAS accreditation for the tests

specified. Samples shall be at least 1m long by the roll width and shall not include the first linear metre of the roll.

6.5.2 Any non-conforming material shall be rejected and shall be removed from the Works. In the event of failure, the two rolls with adjacent sequential reference numbers to the failed roll shall be conformance tested. Any additional testing required as a result of non-conforming material shall be carried out at the expense of the Contractor. Any material installed prior to receipt of the conformance testing results by the Engineer shall be at the Contractor's risk.

6.5.3 The FML shall fully comply with the requirements of either Table 1b or 2b of the Geosynthetic Research Institute (GRI) Test Method GM13 Standard Specification attached at Appendix B.

6.5.4 In addition to the above conformance procedure, if during the installation works, any material appears to be visually defective, the Contractor shall be obliged to replace the material or undertake additional conformance testing as determined by the Engineer.

6.5.5 FML Interface Testing

The interface shear strength of the Geosynthetic Clay Layer and the FML shall be confirmed via direct laboratory testing. The Contractor shall determine the shear strength parameters of each interface in the lining system via a large scale shear box test in accordance with ASTM 5321-08. The test shall be undertaken using actual samples of the lining system materials proposed. The Contractor shall provide the results of the large scale shear box test to the engineer for approval prior to installation of the lining system. (see Section 2.5)

Table 6.5 Conformance Sampling and Testing

Property	Minimum Required Values (all values minimum average)		Test Method	Frequency
	Textured	Smooth		
Thickness (min. ave)	2.00mm (+ 10%)	2.00mm (+ 10%)	In accordance with Table 1b or 2b of the GRI Test Method GM13 Standard Specification	One sample per 5,000m ² or every 5 rolls delivered to site whichever is the greatest number of tests. In the event that materials from different resin sources or manufacturing lines are supplied, at least one additional sample of such material shall be taken and tested
Density (min. ave)	0.940g/cc	0.940g/cc		
Puncture Resistance (min. ave)	534N	640N		
Tear Resistance (min. ave)	249N	249N		
Carbon Black Content (range)	2.0 – 3.0%	2.0 – 3.0%		
Carbon Black Dispersion	Min. 9 of 10 in categories 1 or 2; All of 10 in category 3	Min. 9 of 10 in categories 1 or 2; All of 10 in category 3		
Tensile Properties (min. ave)				

Yield Strength	29kN/m	29kN/m	(Appendix B)	
Break Strength	21kN/m	53kN/m		
Yield Elongation	12%	12%		
Break Elongation	100%	700%		
Stress Crack Resistance	300hrs	300hrs		One sample per 10,000m ² . In the event that materials from different resin sources or manufacturing lines are supplied, at least one additional sample of such material shall be taken and tested

6.6 Subgrade

- 6.6.1 The subgrade shall comprise the upper surface of the GCL which shall be prepared in accordance with this Specification.
- 6.6.2 The Contractor shall ensure that the subgrade surface is firm, smooth, free of foreign matter, free of cracking, free of sharp objects, free of protrusions raised more than 10mm above the surface which could damage the liner and free of abrupt changes in the gradient which could be bridged by the FML. All the foregoing to be to the satisfaction of the Engineer. The Engineer shall record approval of the subgrade in writing using an appropriate record. Example CQA records are attached at Appendix G.
- 6.6.3 The area of subgrade accepted by the Engineer for laying shall be delineated on a daily basis with an agreed location system. Any areas deemed as unsatisfactory by the Engineer and any necessary remedial work required shall be notified to the Contractor for action. The Engineer shall record his agreement that areas of subgrade are satisfactory on a subgrade release form.
- 6.6.4 Areas of the subgrade which have been deemed unsuitable shall, after remediation, be re-inspected by the Engineer to ensure they are acceptable. The FML shall only be laid on areas of subgrade approved in writing by the Engineer on the day of installation.
- 6.6.5 Prior to any FML installation, the Engineer shall inspect the receiving surface to verify that it is fully in accordance with this specification, and that no stones, excessive dust or moisture could be entrapped beneath the FML. No FML shall be installed on an area until the Engineer has granted approval.

6.7 Deployment

- 6.7.1 The FML shall be installed in the location shown on Drawing 2185/2/003 and subsequent details in accordance with the agreed method statement and panel layout.

- 6.7.2 Individual panels shall be positioned with a minimum overlap of 100mm between the adjacent panels. In any case the specific overlap must suit the equipment to be used by the Contractor to enable compliance with the requirements specified. On the side slopes the FML panels shall be installed parallel to the direction of slope (i.e. downslope) and without any horizontal seams on the slope.
- 6.7.3 The method of installation of the FML shall ensure that:
- panels are deployed and seamed one at a time;
 - seaming takes place immediately following deployment;
 - scratches or crimps do not occur as a result of deployment;
 - undulations in the installed FML are minimised as far as practicable. The FML shall not be allowed to fold over or have the potential to fold once loading is applied;
 - equipment does not cause excessive heat or leak hydrocarbons on the FML;
 - adequate and suitable temporary weighting, e.g. sandbags, is provided to ensure no movement occurs during deployment or seaming or at any subsequent time prior to approval by the Engineer of the completed FML installation;
 - no vehicles travel on the FML;
 - sufficient allowance is made for the potential expansion and or contraction of the FML;
 - each panel of FML is marked up with the roll reference and a unique panel identification number.
- 6.7.4 The members of the FML installation crew shall:-
- wear suitable footwear such that damage to the FML does not occur;
 - ensure that no naked flames are used during the works;
 - not smoke at any time when handling or working with the FML;
- 6.7.5 The first 1m length of sheet from each roll shall be discarded and not incorporated within the permanent works.
- 6.7.6 At the perimeter of the cell on the separation bund and the perimeter bunds, the FML shall be secured as shown on Drawing 2185/2/007. Where an anchor trench is used the anchor trench backfill material shall comprise material of the same quality as the liner and shall be compacted in layers not exceeding 150mm using suitable plant.
- 6.7.7 Where the cell abuts another via an existing interphase bund, the FML shall be secured as shown on Drawing 2185/2/007. The existing FML and protective geotextile at the bund toe shall be carefully rolled back to expose the ECL liner of the adjacent cell. A step joint shall be cut in the ECL and the new ECL laid to the specification in Section 4 above. The condition of the existing FML shall be assessed and defective or damaged sheet trimmed away. The new FML shall be welded in accordance with the Specification to the existing HDPE liner with a minimum overlap of 300mm if it is to be extrusion welded or 150mm if it is to be

fusion welded. The arrangement of the FML on the onward joint to subsequent phases shall be as shown on Drawing 2185/2/007.

- 6.7.8 The FML deployment shall be carried out in accordance with the Contractor's proposed panel layout plan and agreed method statement. Any deviation from the proposed layout plan shall be subject to the prior agreement of the Engineer.
- 6.7.9 During installation the Contractor shall measure by survey the panel edges, panel/roll reference numbers, anchor trench positions, patch repair and sample positions and the location and extent of seams welded by extrusion methods to form a fully referenced as-constructed layout plan. The Contractor shall provide to the Engineer the results of the surveys during and on completion of the FML installation.

6.8 Trial Seams

- 6.8.1 At the start of each shift, prior to seaming of the FML, trial seams shall be carried out to confirm the set up of each piece of seaming equipment proposed to be used that work shift in ambient conditions. Trial seams shall be produced under the same conditions as the installation seams and shall be performed with the FML in contact with the same formation type.
- 6.8.2 A trial seam of minimum length 3m shall be carried out for each piece of seaming equipment proposed for use at the beginning of each seaming period, every four hours, on the introduction of a new welding technician, following a prolonged period of shut down and following any significant changes in environmental or operating conditions. All trial seams shall be carried out in the presence of the Engineer.
- 6.8.3 From each trial seam, six tab samples of at least length 105mm by 25mm shall be extracted at random from the length of the seam. The tabs shall be examined by the Engineer to confirm that the seam exhibits a homogenous fusing of the two sheets with no definable boundary or layer. The Contractor in the presence of the Engineer shall test the tabs, three for peel failure and three for shear failure. The mode of failure shall be yield of the sheet material outside the seam. No samples shall fail in the seam. The mode of failure shall be recorded using the code descriptions attached at the rear of Appendix B.
- 6.8.4 If the field testing of the trial seams proves unsatisfactory further trial seams shall be performed and the procedure repeated until the Engineer is satisfied with the set up of the particular item of seaming equipment. The Engineer shall not allow seaming of the FML to commence until successful trial seams are achieved.

6.9 Seaming

- 6.9.1 The Contractor shall make a log of apparatus temperatures and speeds, extrudate temperatures and ambient temperatures at appropriate intervals. All information shall be given to the Engineer on request.

- 6.9.2 All seams shall be individually numbered and recorded by the Contractor. All “T” junctions of adjoining seams shall be covered with an extrusion weld extending to a minimum of 200mm in each direction from the apex of the “T”.
- 6.9.3 The Contractor shall only commence seaming when the following conditions are met:
- The seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material
 - Sheet temperatures are between 5°C and 35°C;
 - If seam overlap grinding is required, that seaming is completed not later than one hour after grinding in order to mitigate oxidation of the sheet;
 - If seam overlap grinding is required, less than 10% of the nominal thickness shall be removed;
 - Grinding does not extend beyond the edges of the weld;
 - Seams are aligned with the fewest possible number of wrinkles and “fishmouths”;
 - Seaming shall not take place during rain or snow or high relative humidity unless proper precautions are taken which allow the seam to be made on dry FML materials;
 - Seaming shall not take place during high winds;
 - Seaming shall not take place above saturated subgrade soils;
 - Seaming shall not take place with standing water on the subgrade soil surface;
 - Seaming shall not take place over frozen subgrade soil.
 - where wrinkles greater than 100mm in height (from the upper surface of the clay liner are identified as being present these shall be removed and patched;
 - On the side slopes the seams shall be installed parallel to the direction of slope (i.e. downslope) and without any horizontal seams on the slope.
- 6.9.4 Any seaming undertaken on sheet with a temperature below 5°C or above 35°C shall be demonstrated to be of the same standard as that undertaken between 5°C and 35°C. The Contractor shall make a written application to the Engineer to undertake seaming outside the specified sheet temperatures. The application shall include a method statement detailing how the Contractor would demonstrate that the seams would be to the same standard as that undertaken between 5°C and 35°C. Natural Resources Wales shall be consulted for acceptance.
- 6.9.5 Only skilled and experienced operators using methods outlined in this Specification shall form seams. The Contractor shall provide the Engineer with the relevant details of his proposed personnel and their experience and this shall include a lead technician and a foreman accredited to a minimum of Level 1 of the BGA/TW1/CS WIP Welding Standard, and all welders accredited to a minimum of Level 2 of the BGA/TW1/CS WIP Welding Standard.

At any time there may be present on site additional crew members who may not be accredited as above and who will carry out duties other than welding activities. There may also be present in any site crew persons who shall be designated as Trainee Technicians. A limit of one Trainee Technician per crew will apply. Trainee Technicians may be allowed to carry out welding activities providing they are at all times under the direct supervision of the Lead Technician accredited to

Level 1 of the BGA/TWI/CSWIP welding standard and they have been registered by their employer for examination for the purpose of accreditation to Level 2 of the BGA/TWI/CSWIP welding standard within three months of their employment date. Personnel who have failed to achieve Level 2 accreditation within three months of their employment date shall not be permitted to undertake any further welding activities on site until they have achieved level 2 accreditation. Copies of Certification shall be provided to the Engineer.

6.9.6 Fusion (hot wedge) Welding

The Contractor shall ensure that:

- a) the conditions detailed at section 6.9.4 above are met prior to the commencement of seaming;
- b) following the completion of the welding of a main panel >25 metres in length a tab/strip sample is removed from each end of the seam and that each sample is tested destructively in the field using peel and shear test methods.
- c) following the completion of the welding of a seam <25 metres in length a tab/strip sample is removed from one end of the seam and that sample is tested destructively in the field using peel and shear test methods.
- d) adequate temporary anchorage is provided to ensure no movement occurs during seaming;
- e) no full width horizontal seams occur on slopes;
- f) the weld temperature and speed are the same as those used when the trial seam was passed

6.9.7 Extrusion Welding

The Contractor shall ensure that:

- a) the conditions detailed at section 6.9.4 above are met prior to the commencement of seaming;
- b) the area to be welded is adequately buffed (no more than 10% of the sheet thickness shall be removed);
- c) grinding does not extend beyond the edges of the weld;
- d) prior to forming an extrusion seam, adjacent panels shall be temporarily secured by heat bonding;
- e) the procedure used to temporarily bond adjacent panels, together with any pre-heating during seaming, shall not cause any damage or overheating to the FML.
- f) temporary bonding using adhesives shall not be permitted.
- g) a copper wire is placed at the join of the two FML sheets if HVE testing is to be undertaken;
- h) when abrasions are made the weld is constructed within 1 hour;
- i) the abrasions extend no further than 10mm either side of the edge of the weld;
- j) the extrudate material used shall be identical in composition to that of the FML sheet.

6.10 Non-Destructive Seam Testing

The Contractor shall maintain full records of all non-destructive testing which shall be provided to the Engineer on a regular basis.

6.10.1 Air Pressure Testing

All twin track fusion seams shall be pneumatically tested. The air channel formed between the twin tracks shall be sealed at its ends and inflated to a minimum pressure of 2 bar (30psi, 200kPa). Following removal of the pressure source the pressure shall be allowed to equalise for 2 minutes. Thereafter there shall be no loss of pressure in the first minute and the pressure shall not decrease by more than 10% over a 5 minute period.

The air compressor shall be turned off during the test period.

To confirm that the full length of seam is pressurised the test shall be carried out such that either:

- The pressure source and gauge are applied to opposite ends of the seam and, on completion of the test, the pressure drop is observed on the gauge following removal of the pressure source; or
- If pressure source and gauge are applied to the same end of the seam, on completion of the test, the channel is deflated from the opposite end of the seam and the pressure drop observed on the gauge.

If a seam fails air pressure testing or indicates a channel blockage, the test length shall be incrementally reduced until the failure area has been clearly identified. In the case of identifiable points of failure, the seam shall be repaired in accordance with the Repair Procedure section, below. If specific points of failure cannot be identified or if the Engineer is not satisfied with the integrity of the seam, the seam shall be repaired by replacement or capping.

The Contractor shall record on the FML, next to the seam, the date, time and air pressures from each air pressure test.

6.10.2 HVE (Spark) Testing

Extrusion seams shall be tested over their entire length using a high frequency continuous coil spark tester. The equipment shall be adjustable in voltage between 0kV and 30 kV and shall generally be operated at a voltage of 10kV per mm of membrane thickness. The spark tester shall be passed slowly in close proximity to the weld to test all points on the weld. Any anomalies in the seam will be identified by the presence of a spark. The location of any sparks shall be marked and the seam repaired in accordance with this specification and re-tested until no sparking is evident.

The Contractor may employ “vacuum box” testing in place of spark testing and the Engineer may request vacuum box testing of any seams at his discretion.

6.10.3 Vacuum Box Testing

Vacuum testing shall employ purpose made equipment, which produces a vacuum over the tested area. A detergent/water solution shall be applied to the full test area prior to application of the test equipment, which will display any leaks by bubbling of the solution. The Engineer shall confirm that no leaks are present under application of the vacuum.

If the seam fails during vacuum box testing, repairs shall be undertaken in accordance with this specification.

6.11 Qualitative Destructive Seam Testing

6.11.1 The Contractor shall cut tab samples from the completed seam in accordance with the criteria set out at section 6.9.6 above and subject them to qualitative destructive testing in peel and shear modes. The seam will be deemed to be acceptable if failure in the tab sample solely occurs in the parent material and does not enter the seam. Should a field tab fail the destructive test the Contractor shall:

- Reconstruct the seam between the two tab locations and re-test or:
- Cut further tabs from each side of the failure point and undertake such destructive testing until a successful result is achieved. The seam shall then be repaired as necessary.

6.11.2 The Engineer may request further tabs for destructive testing at any location on the seams. Under no circumstances shall the cutting of test specimens, FML material or any other materials be permitted above installed FML.

6.12 Quantitative Destructive Seam Testing

6.12.1 The Contractor shall take instruction from the Engineer who shall select where seam samples will be cut for laboratory testing. Those locations will be established as follows:

- Fusion welds will be tested at a minimum frequency of 1 suite per 200m of seam length.
- Extrusion welds will be tested at a minimum frequency of 1 suite per 200m of seam length (with a minimum of 1 if total length of seam <200m) and 1 suite on every day in which 25m or more of seam is completed.
- Test locations shall be determined during seaming at the Engineer's discretion. Suspicion of excess crystallinity, contamination, offset seams, or any other potential of imperfection may prompt the selection of such locations.
- Samples shall be cut from the geomembrane by the Contractor. The Engineer shall witness the sample cutting, and shall number the sample and record the location on the Panel Layout Plan. The Engineer shall also

record the reason for sampling at this location (eg. statistical routine, suspicious geomembrane feature, suspicious welding techniques, etc.)

6.12.2 The Contractor shall cut two 1,000mm long by 300mm wide seam samples from both fusion and extrusion welds for destructive testing by a geosynthetics testing laboratory. One sample shall be retained by the Engineer and the other sent for testing. The testing laboratory shall have UKAS accreditation for each of the tests being undertaken. The frequency of testing shall be in accordance with section 6.12.1 above and Table 6.12, below. However, the Engineer may increase this frequency of sampling if test results indicate problems or poor workmanship.

The Contractor shall ensure that all holes in the FML resulting from destructive seam sampling are immediately repaired in accordance with this specification.

6.12.3 The samples shall either be stored carefully or forwarded to the independent testing laboratory on the same day that they are cut.

6.12.4 Two 25mm wide qualitative tab samples shall be taken associated with each quantitative destructive seam test sample and shall be tested in the field by the Contractor for peel, and shall not fail in the seam.

6.12.5 Laboratory testing shall be carried out on each quantitative destructive seam test sample in accordance with test method ASTM D4437 as modified in NSF Appendix A, with no requirement for sample conditioning time or in accordance with test method ASTM D6392 with 25mm wide strip, testing at 50mm per minute.

6.12.6 The minimum acceptable values to be obtained in the destructive seam tests are those indicated in GRI – GM19 and Table 6.12, below. At least five specimens will be tested for each test method. Specimens will be selected alternately by test from the samples (eg. peel, shear, peel, shear, etc.).

6.12.7 A destructive test failure is deemed to occur if:

two or more specimens fail in “peel separation”
OR
two or more specimens fail in “shear elongation”

6.12.8 Failure is deemed to have occurred if either the hand tensiometer OR the Engineer’s samples fail within the seam.

6.12.9 In the event of a test failure, the Contractor shall have two options:

- To reconstruct the seam (e.g. remove the old seam and reseam) between any two test locations where tests have confirmed the seam meets the Specification.
- To trace the welding path to an intermediate location, 3m minimum from the location of the failed test (in each direction) and take a small sample for an additional field test at each location. If these additional samples pass the field

tests, then full laboratory samples shall be taken. If these laboratory samples pass the tests, then the seam shall be reconstructed between these locations by capping. If either sample fails, then the process shall be repeated to establish the zone in which the seam shall be reconstructed. All acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. In cases exceeding 50m of reconstructed seam, a sample will be taken from within the reconstructed zone. This sample must pass the destructive testing or the procedure described in this section must be repeated.

Table 6.12
Peel Strength and Shear Strength Parameters

Property	Test Method	Units	Required Values	Conformance Testing Frequency
Fusion:				
Shear Strength	ASTM 6392	N/mm	28 (min)	1 suite per 200m of seam
Shear Elongation	ASTM 6392	%	50 (min)	1 suite per 200m of seam
Peel Strength	ASTM 6392	N/mm	21 (min)	1 suite per 200m of seam
Peel Separation	ASTM 6392	%	25 (max)	1 suite per 200m of seam
Extrusion:				
Shear Strength	ASTM 6392	N/mm	28 (min)	1 suite per 200m of seam (with a minimum of 1 if total length of seam <200m) and 1 suite on every day in which 25m or more of seam is completed.
Shear Elongation	ASTM 6392	%	50 (min)	
Peel Strength	ASTM 6392	N/mm	18 (min)	
Peel Separation	ASTM 6392	%	25 (max)	

6.13 Repair Procedure

6.13.1 The Contractors shall discuss and agree with the Engineer his proposed repair procedures, materials and techniques prior to the commencement of repair work. In addition:

- i) all surfaces shall be clean and dry at the time of repair;
- ii) all abraded areas shall be completely covered by the weld or patch; patches or caps shall extend at least 150mm beyond the edge of the defect and all corners of patches shall be rounded to a radius not less than 75mm .

6.14 Installation Approval

6.14.1 The installed FML shall be subject to the inspection and approval of the Engineer prior to the placement of the protective geotextile at any location. Approval shall be made on the basis of the following:

- Visual inspection to confirm that all stones, extrusion weld materials or any other potentially deleterious materials have been removed from the surface of the FML; that there are no visible surface defects such as excessive scratching and no folds or excessive undulations; and that the appropriate overlap between adjacent panels has been achieved;
- All necessary repairs have been made and their locations recorded;
- All tests to seams, patches and repairs have been completed and recorded and the results of respective laboratory destructive seam testing have been received and assessed as satisfactory by the Engineer;
- Areas for approval have been clearly defined by suitable means.

6.14.2 The Engineer will confirm approval of installation compliance. Approved areas not covered in a timely manner will be subject to re-cleaning and re-inspection.

6.14.3 On completion of installation the Contractor shall submit to the Engineer a fully referenced as-constructed layout plan showing panel/roll reference numbers, seam types and any repair and sample locations.

7 GEOTEXTILE MATERIAL

7.1 General

7.1.1 The Contractor shall supply and install a Protection Geotextile comprising of prime quality polypropylene fibre (UV stabilised) with no post consumer fibres in all locations where an FML is installed. The primary purpose of the Protection Geotextile is to prevent the drainage stone damaging the FML liner. The detail of the lining system is shown on Drawings 2185/2/006 & 007.

7.1.2 The Contractor shall supply and lay a Filter Geotextile comprising of prime quality polypropylene fibre (UV stabilised) with no post consumer fibres in locations detailed upon Drawings 2185/2/007 & 006 . The primary purpose of the Filter Geotextile is to protect the leachate drainage aggregate from fines within the waste.

7.2 Geotextile Manufacture

7.2.1 Protection Geotextiles to be used shall be manufactured from non-woven woven or a combination of non woven and woven sheets of polypropylene fibres. The combination sheets shall be bonded by needle punching. The protective geotextile shall conform to the following criteria:

Protective Geotextile Criterion	Unit	Minimum Value	Test
Tensile Strength Machine Direction	KN/m	20	Tensile Strength BSEN ISO 10319
Tensile Strength Cross Machine Direction	KN/m	20	Tensile Strength BSEN ISO 10319
CBR Puncture Resistance/Plunger Displacement	KN, mm	To be approved by the Engineer	BSEN ISO 12236
Mass Per Unit Area	Kg /m ²		BS EN 965
Thickness	mm		BS EN 964-1
Polymer		Polypropylene	
Bonding		Needle Punched	
Construction		Non- Woven, woven or a combination of the two types.	

The above values are typical which indicates the mean value derived from the samples taken for any one test as defined in the BSEN ISO standard (usually the mean of five specimens).

7.2.2 Filter Geotextiles to be used shall be manufactured from non-woven sheets of polypropylene fibres. The filter geotextile shall conform to the following criteria:

Filter Geotextile Criterion	Unit	Minimum Value	Test
Tensile Strength Machine Direction	KN/m	15	Tensile Strength BSEN ISO 10319
Tensile Strength Cross Machine Direction	KN/m	15	Tensile Strength BSEN ISO 10319
CBR Puncture Resistance/Plunger Displacement	KN, mm	3.3	BSEN ISO 12236
Characteristic opening size O90		50 to 120 µm	EN ISO 12956
Water permeability normal to plane	l/m2s	>40	EN ISO 11058
Mass Per Unit Area	Kg /m ²	0.3	BS EN 965
Thickness	mm	1.5 (min)	BS EN 964-1
Polymer		Polypropylene	
Bonding		Needle Punched	
Construction		Non- Woven	

The above values are typical which indicates the mean value derived from the samples taken for any one test as defined in the BSEN ISO standard (usually the mean of five specimens).

7.2.3 In respect of the Protection Geotextile the Contractor shall propose a combination of leachate drainage stone from a specified source and protective geotextile to the Engineer. The Contractor shall ensure that the combination of FML, geotextile and drainage stone proposed has passed the Cylinder Test (*LFE 2 Cylinder Testing Geomembranes and their protective materials issued by the Environment Agency*) with a deflection of less than 0.25% for both Scenario 1 and Scenario 2. The Engineer will consider applications for varying geotextile properties for

differing waste loadings. The criteria for testing shall be instructed by the Engineer.

- 7.2.4 The Contractor shall determine the shear strength parameters of the protective geotextile to FML interface in the lining system via a large scale shear box test in accordance with ASTM 5321-08. The test shall be undertaken using actual samples of the lining system materials proposed. The Contractor shall provide the results of the large scale shear box test to the engineer for approval prior to installation of the lining system. (see section 2.5).
- 7.2.5 The Contractor shall supply reference samples of the proposed leachate drainage stone and protective geotextile to the Engineer. His proposal must be supported by at least two results from a Cylinder Test performed by a laboratory acceptable to the Engineer which prove to the satisfaction of the Engineer that the combination of FML, geotextile and drainage stone will result in performance in the cylinder test above the minimum specified. The Engineer shall, when he is satisfied that the materials proposed are compliant, issue written approval for the combination.
- 7.2.6 After issue of written approval, if the Engineer suspects that the combination of FML, geotextile and drainage stone may not be within specification, for whatever reason, the Contractor shall carry out such further cylinder tests as may be required by the Engineer to prove the combination produces results acceptable to him. The Contractor shall supply the Engineer all results of all tests required by the Engineer within 24 hours of them becoming available. All costs of testing shall be borne by the Contractor.
- 7.2.7 The Contractor shall provide to the Engineer confirmation from the geotextile manufacturer that the geotextile has been tested in the factory to detect needle fragments and that there is a robust process in place for detecting and removing these prior to the product leaving for the site. This confirmation shall also specify the accuracy of the testing.

7.3 Geotextile Installation

- 7.3.1 Before the geotextile is laid the Contractor shall ensure that the surface of the FML or leachate drainage stone is completely cleared of any material that might harm the geotextile.
- 7.3.2 Geotextiles shall be installed in strict accordance with the Specification and Drawings and to the parameters specified in Section 7.2.1, Section 7.2.2 and Section 7.2.3 or such other parameters as may be agreed by the Engineer.
- 7.3.3 Adjacent geotextile panels shall be overlapped by a minimum of 300mm and secured using an in situ heat bonding technique or stitching technique acceptable to the Engineer. Any alternative (proposed) jointing technique shall be approved in writing by the Engineer prior to use.

- 7.3.4 The method of installation of the geotextile shall ensure that:
- a) adequate temporary anchorage is provided to ensure no movement occurs during seaming;
 - b) panels are placed one at a time;
 - c) seaming takes place immediately following deployment.
- 7.3.5 All personnel working on the geotextile shall wear suitable footwear such that it is not damaged and smoking shall not be permitted during the handling, deployment and seaming of the geotextile.
- 7.3.6 Operation of construction plant directly on the installed geotextile shall not be permitted.
- 7.3.7 Seams shall be oriented parallel to the line of the slope (i.e. directly down slope) and horizontal seams shall not be permitted on the slope.
- 7.3.8 Seams shall be made only by skilled and experienced operators using methods outlined by this Specification.
- 7.3.9 The procedure used to temporarily bond adjacent panels together shall not damage the geotextile or the underlying FML or drainage aggregate and particular care shall be required to ensure the temperature of hot air at the nozzle of any spot seaming aperture is controlled such that no damage occurs to the geotextile or the underlying FML. Temporary bonding by adhesives shall not be permitted.
- 7.3.10 Placing of the drainage layer shall not be permitted until the results of the quality assurance testing are available and the results indicate the ECL has been installed in accordance with the requirements of the Specification.

7.4 Geotextile Contractual QA/QC Requirements

- 7.4.1 All geotextiles shall be approved in writing by the Design Engineer, and sources of supply shall not be changed without his approval.
- 7.4.2 The Contractor shall obtain the following information from the manufacturer or supplier of the geotextile for each separate consignment of each material delivered to the Site:-
- a. Product name and grade/no.
 - b. Name and address of producer/supplier
 - c. Batch or code number
 - d. Geotextile roll number
 - e. Roll length and width
 - f. Roll weight in kilogramme
 - g. Polymer type.
 - h. Manufacturing characteristics

Each consignment shall be numbered and the delivery date recorded. A consignment is considered to be the number of rolls or packages delivered at one time and may be split into batches for the purposes of sampling and testing. The above information shall be given to the Engineer.

7.4.3 Samples shall be taken from rolls of protective geotextile selected by the Engineer. Samples shall be submitted by the Engineer for conformance testing at a laboratory to confirm that the properties of the material meet the manufacturer's specification. All conformance testing shall be undertaken at an independent laboratory with UKAS accreditation for the tests specified. Samples shall be 1m long by the roll width and shall not include material from the first 5 linear metres of the roll.

7.5 Conformance Testing

7.5.1 The Engineer will reject protective material not achieving the requirements of the conformance testing as set out in paragraph 6.2 of the Environment Agency's document LFE 7 "Using Nonwoven protector geotextiles in landfill engineering".

7.5.2 The Contractor shall note that a consignment (delivery lot) is considered to fail if one or more samples tested do not meet one or more of the declared values on the CE declaration or relevant application properties. The Contractor may choose to replace the rejected lot or to carry out further testing (to enable the evaluation of conformity by statistical procedure to be undertaken) on new samples from the product delivered to the site. The results on the previously tested samples shall be included in the evaluation.

7.5.3 In addition to the above conformance procedure, if any material appears to be visually defective upon installation it shall be removed to an extent as directed by the Engineer who may request additional conformance testing. This additional testing shall be carried out at the expense of the Contractor.

7.5.4 The source of protective geotextile shall undergo the conformance testing detailed in Table 7.5.1.

Table 7.5.1 Protective Geotextile Conformance Testing Requirements

Property	Test Method	Units	Typical Mean Value	Test Frequency	Tolerance
Thickness @ 2kPa	BSEN ISO 9863-1	mm	**	1/2500m ² or part thereof	
CBR Puncture Resistance Displacement	BSEN ISO 12236	kN mm	**	1/6000m ² or part thereof	-10%
Tensile Strength (md)	BSEN ISO 10319	kN/m	20	1/6000m ² or part thereof	-10%
Tensile Strength (cmd)	BSEN ISO 10319	kN/m	20	1/6000m ² or part thereof	-10%
Extension (md)	BSEN ISO 10319	%	**	1/6000m ² or part thereof	+/-30% of typical mean value

Extension (cmd)	BSEN ISO 10319	%	**	1/6000m ² or part thereof	+/-30% of typical mean value
Resistance to perforation (cone drop test)	BSEN ISO 13433	mm	**	1/6000m ² or part thereof	+2mm
Mass per unit area	BS 965	g/m ²	**	1/2500m ² or part thereof	
Durability (according to annex B: EN 13253):					
Resistance to weathering (UV) @ 50MJ/m2 radiant exposure	BSEN 12224	Retained Strength			>80% of typical mean value
Resistance to Oxidation (100 years)	EN ISO 13438	Retained Strength after 56 days			>50% of typical mean value
Resistance to liquids	BSEN 14030	Retained Strength			>50% of typical mean value
	Durability test data supplied by the manufacturer – with a test frequency not exceeding 3 years will be admissible.				

** As specified by the manufacturer for product complying with the stated requirements.

The Contractor shall provide a panel record plan recording the location of each panel of geotextile placed as protective geotextile, its serial number, the location of any repairs.

- 7.5.5 The source of filter geotextile shall undergo the conformance testing detailed in Table 7.5.2.

Table 7.5.2 Filter Geotextile Conformance Testing Requirements

Property	Test Method	Units	Typical Mean Value	Test Frequency	Tolerance
Thickness @ 2kPa	BSEN ISO 9863-1	mm	1.5	1/2500m ² or part thereof	
CBR Puncture Resistance Displacement	BSEN ISO 12236	kN mm	3.3	1/6000m ² or part thereof	-10%
Tensile Strength (md)	BSEN ISO 10319	kN/m	15	1/6000m ² or part thereof	-10%
Tensile Strength (cmd)	BSEN ISO 10319	kN/m	15	1/6000m ² or part thereof	-10%
Resistance to perforation (cone drop test)	BSEN ISO 13433	mm	**	1/6000m ² or part thereof	+2mm

Water permeability normal to plane	EN ISO 11058	l/m2s	>40	1/6000m2 or part thereof	
Mass per unit area	BS 965	g/m ²	300	1/2500m ² or part thereof	
Durability					
Resistance to weathering (UV) @ 50MJ/m2 radiant exposure	BSEN 12224	Retained Strength after 1 month			>80% of typical mean value
Microbiological Resistance	BSEN 12225	Retained Strength			**
Resistance to liquids	BSEN 14030	Retained Strength			**
	Durability test data supplied by the manufacturer – with a test frequency not exceeding 3 years will be admissable.				

** As specified by the manufacturer for product complying with the stated requirements.

The Contractor shall provide a panel record plan recording the location of each panel of geotextile placed as filter geotextile, its serial number, the location of any repairs.

7.6 Geotextile Repair Procedure

- 7.6.1 The Contractor shall repair all geotextile damage, determined by inspection or testing, including areas for sheet samples, as follows:-

Faults shall be cut back to give clean and dry interfaces, free from imperfections. They shall then be covered with an appropriate shaped patch of the same material as the geotextile to give a minimum 300 mm overlap in all directions which shall then be secured using an acceptable in situ heat bonding technique or stitching. Repairs for making good areas removed for random samples for testing shall also be carried out by this method.

- 7.6.2 The Contractor shall provide to the Engineer full written details of all repairs and the method of repair undertaken.

7.7 Geotextile Validation

- 7.7.1 The Contractor shall install additional sacrificial patches of protective geotextile (2 vertical rows of 1m x 1m installed at 5 linear metre interval up slope) that shall be heat bonded to the underlying protective geotextile. These patches shall be removed and forwarded for testing as part of the future stone lift CQA works.

8 SUMPS AND PIPEWORK

8.1 General

- 8.1.1 The Contractor shall provide and install leachate extraction chambers and monitoring points at the locations shown on Drawing 2185/2/003 and to the detailed arrangement shown on Drawing 2185/2/006.

8.2 Leachate Extraction Chambers and Leachate Monitoring Points

8.2.1 General

The Contractor shall provide and install leachate extraction chambers in the locations shown on Drawing 2185/2/003 and to the detail shown on Drawing 2185/2/006.

8.2.2 Formation Level

The Contractor shall excavate a depression to accommodate the reinforced pad specified in Section 3.5.3 such that the finished reinforced pad installation is a depression 4.6 metres x 4.6metres x 0.3 metres deep with sidewalls at 45 degrees.

8.2.3 Engineered Clay

The Contractor shall provide and lay 500 mm of engineered clay on the base and sides of the depression in accordance with Section 4 of this specification. The finished profile of the engineered clay shall be in accordance with the detail shown on Drawing 2185/2/006. The profile shall be aligned with the depression in Section 8.2.2 above in the formation level so that the required thickness of clay is not prejudiced.

8.2.4 GCL

The Contractor shall provide and lay GCL on the base and sides of the depression in the engineered clay. The GCL beneath the chambers shall be integral with the GCL on the remainder of the cell base and shall be laid in accordance with Section 5. In addition, the Contractor shall provide and lay 1 extra layer of GCL beneath the concrete base.

8.2.5 FML

The Contractor shall provide and lay FML on the base and sides of the depression in the engineered clay. The FML shall be integral with the FML on the remainder of the cell base and shall be laid in accordance with Section 6. In addition the Contractor shall provide and lay an extra sacrificial layer of FML on the base and sides of the depression in the engineered clay above the integral FML layer.

8.2.6 Protection Geotextile

The Contractor shall provide and lay protection geotextile as specified in Section 7 above. The geotextile shall be integral with the other geotextile at the base of the site. In addition, the Contractor shall provide and lay 1 extra layer of protection geotextile above the integral layer of geotextile.

8.2.7 Visqueen

The Contractor shall provide and lay a layer of Visqueen 1200 polyethylene membrane above the protection geotextile in Section 8.2.6 above.

8.2.8 Concrete and Reinforcement

The Contractor shall provide and construct a reinforced concrete slab in the depression specified above. The slab and reinforcement shall be A252 mesh set in two layers mutually at right angles, laid at 75mm from the bottom. The mesh shall be covered by C32/40 concrete such that there is at least a 75mm cover on the reinforcement in all directions. The connection reinforcement shall be T10 bars linked with the A252 mesh. The T10 bars shall be 900mm long and bent to a right angle at 700/200 mm point. The 700mm side shall be set vertically. Connection bars shall protrude at least 400 mm from the top of the concrete slab. Each bar shall be set at 200 mm centres and shall be covered by C25/30 concrete such that there is at least a 75mm cover on the reinforcement in the finished structure. The concrete shall be made with sulphate resistant cement and have a minimum cement content of 360kg/m^3 and a maximum water/cement ratio of 0.45. The base of the slab shall be nominally 3 metres x 3 metres x 300 mm thick. The contractor shall also fill the tapering fillet around the 3 x 3 slab with concrete so that the depression is full of concrete. The concrete shall be allowed 7 days to gain strength before any superimposed load is placed on it.

Sampling and testing of fresh and of hardened concrete shall comply with BS 1881.

- One sample of concrete shall be taken from each 20m^3 of concrete delivered with a minimum of one sample of concrete on each day that concrete is used.
- Three cubes shall be made from each sample.
- Compliance with the characteristic strength shall be based on tests made on cubes at an age of 28days. The mean of the results shall be taken as the test result. When the difference between the results divided by their mean exceeds 15%, the test result shall be deemed invalid.

For compliance purposes:

1. the average strength determined from any group of four consecutive test results shall exceed the specified characteristic strength (30 N/mm^2) by not less than 7.5 N/mm^2 .
2. each individual test result shall be greater than 85% of the specified characteristic strength.

8.2.9 Precast Concrete Manhole Rings

The Contractors shall provide and install 4 precast concrete manhole rings made with sulphate resistant cement 1 metre high and 1.050 metres diameter. The rings shall be sleeved with a 150mm thickness of C32/40 grade concrete with a 2 layers of A142 mesh fabric set centrally within it. The lower 2 metres of chimney shall be perforated with 50mm diameter holes at 300mm centres around the full perimeter to allow leachate penetration. The perforations shall be carried through the reinforced concrete sleeve. The rings shall be set in the centre of the concrete slab. The outer surface of the sleeve around the upper two manhole rings shall be covered with two layers of Visqueen 1200 polyethylene membrane fastened with nylon industrial fastening bands at least 14 mm wide, every metre vertically. The Concrete sleeve shall be terminated 400mm below the top of the uppermost rings with 400mm of mesh fabric showing so that the sleeve and mesh fabric for the next vertical extension of the chimney can be effectively tied in.

The operator shall ensure that gas-tight caps are fitted to all pipe ends and chambers where open to the atmosphere and or likely to cause uncontrolled release of landfill gas.

8.3 Leachate Extraction Sidewall Risers

8.3.1 General – The Contractor shall provide and install two leachate extraction sidewall risers at the locations shown on Drawing 2185/2/003 and to the detail shown on Drawing 2185/2/006. The pipework shall penetrate the leachate extraction chamber.

8.3.2 The Contractor shall supply and install pipes with a suitable strength rating such that the diameter of the pipes shall not be reduced by any more than 5% when installed within the leachate drainage layer as detailed on the Drawings and overlain by the expected thickness of waste. The pipes shall also be in accordance with the following:-

Product	Specification
250mm External Diameter Single walled HDPE	Minimum slot or perforation area of 1.5%. Pipe to be slotted over the upper two third of its circumference

8.3.3 The Contractor shall submit the following information to the Engineer for approval prior to the installation of the leachate collection pipework:

- (i) Details of his proposal for leachate collection pipework and fittings including proposed SDR of the pipework;
- (ii) Details from the pipe manufacturer to demonstrate that the tensile strength/pipe stiffness parameters of the proposed pipe are not adversely affected by an increase in temperature, for example above an ambient temperature of 50°C.
- (iii) Copies of the pipe manufacturers' quality control documentation;
- (iv) Copy of the manufacturers' recommendations for storage and installation;

- (v) A summary of his experience in the installation and welding of leachate collection pipework;
- (vi) Calculations from the pipe manufacturer to demonstrate that the pipe meets the following requirements:
 - Pipe deflection <5%
 - D85/hole diameter >1.0 (Circular Perforations)
 - D85/slot width >1.2 (Slotted Perforations)
 - Pipe Stress

Where D85 refers to the particle size of the drainage blanket material for which 85% is less than that size.

The following assumptions can be made:

- Uncompacted but confined gravel surround
- Waste depth and loading information – to be confirmed by the Engineer on request

8.3.4 The Contractor shall make the joints between lengths of the pipe and junctions between pipe runs only with purpose made fittings supplied by the manufacturers of the pipe. All sections of the leachate collection pipework shall be firmly fixed together using butt fusion or electro fusion welding techniques. Push fit couplings and hand welding techniques will not be acceptable. The contractor shall submit to the Engineer his proposal for the method of jointing for his approval. The upgrade ends of all pipes shall be fitted with caps provided by the manufacturers.

8.3.5 Where butt-welding is used, a fully automatic machine shall be used which shall:

- automate trimming of pipe faces;
- automate determination of drag forces during all stages of jointing process;
- automate incorrect heater temperature lock out;
- automate heater plate ejection;
- automate bead formation control;
- warn of and record incomplete cooling times.

In addition, the machine shall be capable of recording and storing weld specific parameters such as heater temperature, bead pressure, heat soak time, fusion pressure and actual and target cooling times. It shall also record the date, time, operator and joint number. This data shall be retrievable by a data capture unit and a digital and printed copy supplied to the Engineer on the following working day.

8.3.6 The Contractor shall install the pipes with a full haunch of leachate drainage aggregate under each side ensuring that the pipe is properly bedded to provide the required support.

8.3.7 The drainage stone surrounding the leachate pipework shall be firmly compacted to support the pipework.

9 LEACHATE DRAINAGE LAYER

9.1 General

- 9.1.1 The leachate from the waste deposited in the cell shall be collected by a 500mm thick layer of drainage aggregate. The Contractor shall supply and place a 500mm thick layer of drainage aggregate over the entire base and up the sloping surface of the side slopes as shown on the Drawings. Where the drainage aggregate is placed under a target pad its thickness shall be increased to 1,000mm or as otherwise shown on the Drawings.

9.2 Drainage Aggregate

- 9.2.1 Drainage Aggregate shall be fines free stone aggregate approved by the Engineer. The Contractor shall ensure that the aggregate, as placed, complies with the following specification:-

Test	Acceptance Criteria
10% fines value BS 812 Part 111: 1990	>100 kN (Soaked Test)
Direct permeability Test HA 41/90 Design Manual For Roads and Bridges Volume 4 Section 2	$\geq 1 \times 10^{-2}$ m/s
Particle Size Distribution BS 812 Part 103	As BS 13242 (see below) for 20/40mm sized material

- 9.2.2 The Contractor shall remove from the drainage stone any concentrations of sharp or angular aggregate likely, in the opinion of the Engineer, to be deleterious to the geotextile.

9.3 Testing of the Drainage Aggregate.

- 9.3.1 The drainage aggregate shall be tested 3 times for each source to confirm the target placement permeability of 1×10^{-2} m/s.

The Engineer will sample the drainage aggregate at least every 1000 tonnes placed for 10% fines values and particle size distribution and shall evaluate the results to ensure that the grading of the as placed material has not changed substantively from that stated in section 9.2 above.

9.4 Placement

- 9.4.1 The Contractor shall undertake the placement of the leachate drainage layer material with minimal trafficking and handling and in such a manner that causes no damage to, or displacement of, underlying layers and such that no wrinkles develop in the protection geotextile.
- 9.4.2 Plant used to place the leachate drainage layer shall under no circumstance be driven directly on the underlying layers other than for safety of the Works. A

minimum thickness of 1m of material shall be maintained beneath wheeled vehicles. The blanket shall be placed and not spread using tracked 360° excavator operating from a minimum thickness of 500mm of blanket material.

9.4.3 In general the methods employed shall comprise the following:

- Tipping of fresh material on previously placed material.
- Casting material by 360° excavator (using a bucket without teeth).
- Pushing of material up and over the face of the tipped load allowing it to fall vertically onto the geotextile.
- Pre-loading of the geotextile with discrete mounds of material, to prevent the generation of excessive wrinkles or folds, and in-filling between mounds.

9.4.4 The Contractor shall remediate any damage to the underlying material in accordance with the Contract and to the satisfaction of the Engineer who will determine the extent of the remedial work.

9.4.5 The Contractor shall excavate mini trial pits to facilitate the Engineer who shall undertake a physical thickness check on a 25 metre grid prior to the survey in Section 2.4 being undertaken.

9.5 Leachate Drainage Layer Interface Testing

The Contractor shall determine the shear strength parameters of the drainage aggregate to protective geotextile interface in the lining system via a large scale shear box tests in accordance with ASTM 5321-08. The test shall be undertaken using actual samples of the lining system materials proposed. The Contractor shall provide the results of the large scale shear box test to the engineer for approval prior to installation of the lining system. (see section 2.5).

9.6 Target Pads

9.6.1 The Contractor shall construct target pads at the locations shown on Drawing 2185/2/003, to the detail shown on Drawing 2185/2/006. The leachate drainage layer shall be thickened to 1 metre thick over the full extent of the target pad and shall be placed as lateral support to the target pad on the surrounding 1 in 2 batter. The Target pad shall be nominally 10m x 10m on its top surface and be 1 metre thick and have perimeter batters sloped at 1 in 2. The target pad shall be formed with a clean no fines hardcore made substantially out of orange engineering brick or other suitably visually indicative material approved by the Engineer. The upper surface shall be covered with a red or orange geotextile. The geotextile shall be kept in place by placing a thickness of 150mm of hardcore material around its perimeter to weigh it down. The Contractor shall place the hardcore using an excavator fitted with low ground pressure tracks using methods agreed in writing with the Engineer.

9.7 Leachate Overflow Points

9.7.1 Section deleted.

10 GEOCOMPOSITE DRAINAGE LAYER (GDL)

10.1 General

10.1.1 Additional sidewall drainage shall be placed against the flank of Cell 13 in order to drain leachate into the proposed Valley Cell leachate drainage system and encourage gas to flow up to the gas collection infrastructure.

10.1.2 The GDL will be a double cuspated HDPE layer with geotextile layers adhered both above and below.

10.1.3 The Contractor shall supply and install a GDL over the area shown on Drawing 2185/2/004. The drain shall be Pozidrain 7D240D/NW8 or equivalent approved by the Engineer. The required characteristics are shown in Table 10.1 below.

10.1.4 The exact extent of deployment of the drain shall be agreed on site after exposure of the cover soil to Cell 13 and confirmation of the extent of waste placement at the toe of the slope. The GDL will be terminated 500mm outside the waste edge at the toe of slope. The northern and eastern extent shall be defined by the recorded position for the cell boundary at its base.

Table 10.1 – Drainage Geocomposite Requirements

PARAMETER	TEST METHOD	REQUIREMENT
GEOTEXTILE		
Thickness at 2kPa	EN ISO 9863-1	8.6mm
Material		Polypropylene
Tensile Strength (MD/CMD)	EN ISO 10319	>9.5/>9.5kN/m
Pore Size O ₉₀	EN ISO 12956	<120micron
Static Puncture Resistance CBR	EN ISO 12236	≥1600N
Dynamic Cone Drop Perforation	EN ISO 13433	≤32mm
GEOCOMPOSITE PROPERTIES		
Thickness at 2kPa	EN ISO 9863-1	1.2mm
Mass per Unit Area	EN ISO 9864	890g/m ²
Usable Tensile Strength (MD/CMD)	EN ISO 10319	≥28/19kN/m
Elongation at Peak (MD/CMD)	EN ISO 10319	≤45/45%

Static Puncture Resistance CBR	EN ISO 12236	$\geq 4,300\text{N}$
SHEET WATER FLOW		
Perpendicular Water Flow @ 20kPa confining pressure, HG=1.0	EN ISO 11058	$>1.2 \text{ l/m/s}$
Perpendicular Permeability @2kPa head	EN ISO 11058	$2.5 \times 10^{-3} \text{ m/s}$

All values quoted are subject to Pozidrain tolerances stated on specification sheet. Equivalent materials must at minimum match Pozidrain values less tolerance

- 10.1.5 The Contractor shall install and anchor the GDL in accordance with the manufacturer's installation advice and shall ensure that the full lateral overlap is correctly installed. At the lower end of each sheet where a joint is to be made the Contractor shall peel back the geotextile for a distance of 300mm and inset the new panel inserted between the cusate and the geotextile of the higher sheet.
- 10.1.6 The interface shear strength of the GDL and the formation surface shall be confirmed via direct laboratory testing. The Contractor shall determine the shear strength parameters of each interface in the lining system via a large scale shear box test in accordance with ASTM 5321-08. The test shall be undertaken using actual samples of the lining system materials proposed. The Contractor shall provide the results of the large scale shear box test to the engineer for approval prior to installation of the lining system. (see Section 2.5)

11 ELECTRICAL RESISTIVITY LEAK TESTING (ERLT)

- 11.1 The Contractor shall arrange for an ERLT to be carried out by a qualified experienced sub-contractor on the area of the fully prepared FML liner after placement of protective geotextile and leachate drainage aggregate in areas where leachate drainage is required and after the placement of protective geotextile in other areas.

The Contractor shall ensure their method of working ensures that FML beneath target pads can be surveyed.

- 11.2 The Contractor shall make all necessary arrangements to enable a successful survey to take place including, but not exclusively, provision of any labour, pumping of water, wetting of the drainage layer or exposure of the upper levels of the FML.
- 11.3 The sub-contractor shall fully investigate all anomalies detected, including those introduced by the Engineer (see CQA Method statement), regardless of where they occur, by excavation of the relevant layers, to expose the likely area of the defect in the FML. The area exposed shall be sufficient to allow its repair to the satisfaction of the Engineer.

- 11.4 During any FML repair / investigative work the whole area of any damaged protective geotextile shall be covered by a new section of geotextile with a minimum 300mm overlap in all directions. The leachate drainage layer and any infrastructure shall then be carefully replaced. The quality of the repair shall be checked by retesting using the ERLT methods. The Contractor shall provide a copy of the final certification report from the specialist sub-contractor within 10 working days of the completion of his work on Site. The FML shall be repaired in accordance with this specification.

APPENDIX B

GRI Test Method GM13

“Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”

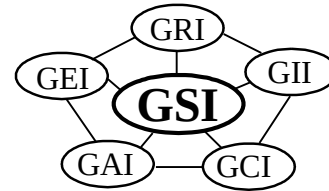
&

GRI Test Method GM19

“Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes”

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Revision 12: November 14, 2014
Revision schedule on pg. 11

GRI Test Method GM13*

Standard Specification for

“Test Methods, Test Properties and Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

- 1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.
- 1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.
- 1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

- 1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

- D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
- D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheet
- D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
- D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
- D 1603 Test Method for Carbon Black in Olefin Plastics
- D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
- D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
- D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
- D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
- D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
- D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
- D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
- D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
- D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
- D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
- D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

2.2 GRI Standards

- GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

- 2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.

ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.

ref. EPA/600/R-93/182

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

- 4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.
- 4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.
- 4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.
- 4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- | | |
|------------------------------|--------------------------|
| • Volatile Loss | • Water Absorption |
| • Dimensional Stability | • Ozone Resistance |
| • Coeff. of Linear Expansion | • Modulus of Elasticity |
| • Resistance to Soil Burial | • Hydrostatic Resistance |
| • Low Temperature Impact | • Tensile Impact |
| • ESCR Test (D 1693) | • Field Seam Strength |
| • Wide Width Tensile | • Multi-Axial Burst |
| • Water Vapor Transmission | • Various Toxicity Tests |

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)
- Trouser Tear (see Note 7)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

- 7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.
- 7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.
- 7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

- 8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

- 9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

- 10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.)	D5199	nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density mg/l (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties (1) (min. ave.)	D 6693 Type IV	63 lb/in. 114 lb/in.	84 lb/in. 152 lb/in.	105 lb/in. 190 lb/in.	126 lb/in. 228 lb/in.	168 lb/in. 304 lb/in.	210 lb/in. 380 lb/in.	252 lb/in. 456 lb/in.	20,000 lb
• yield strength		12%	12%	12%	12%	12%	12%	12%	
• break strength		700%	700%	700%	700%	700%	700%	700%	
• yield elongation									
• break elongation									
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	54 lb	72 lb	90 lb	108 lb	144 lb	180 lb	216 lb	45,000 lb
Stress Crack Resistance (2)	D5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI-GM10
Carbon Black Content (range)	D 4218 (3)	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lb
Carbon Black Dispersion	D 5596	note (4)	note (4)	note (4)	note (4)	note (4)	note (4)	note (4)	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) (5)									200,000 lb
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
— or —									
(b) High Pressure OIT	D 5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C (5), (6)	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	55%	55%	55%	55%	55%	55%	55%	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance (7)	D 7238								
(a) Standard OIT (min. ave.)	D 3895	N.R. (8)	N.R. (8)	N.R. (8)	N.R. (8)	N.R. (8)	N.R. (8)	N.R. (8)	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)	D 5885	50%	50%	50%	50%	50%	50%	50%	

- (1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.
- (2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
- (3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
- (4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
- (5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - mils (min. ave.) • lowest individual of 10 values	D5199	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	per roll
Density (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (1) (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	11 kN/m 20 kN/m 12% 700%	15 kN/m 27 kN/m 12% 700%	18 kN/m 33 kN/m 12% 700%	22 kN/m 40 kN/m 12% 700%	29 kN/m 53 kN/m 12% 700%	37 kN/m 67 kN/m 12% 700%	44 kN/m 80 kN/m 12% 700%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	240 N	320 N	400 N	480 N	640 N	800 N	960 N	20,000 kg
Stress Crack Resistance (2)	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM-10
Carbon Black Content - %	D 4218 (3)	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	9,000 kg
Carbon Black Dispersion	D 5596	note (4)	note (4)	note (4)	note (4)	note (4)	note (4)	note (4)	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (5) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	90,000 kg
Oven Aging at 85°C (5), (6) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	per each formulation
UV Resistance (7) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)	D 7238 D 3895 D 5885	N. R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	per each formulation

- (1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
- (2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
- (3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
- (4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
- (5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) (1)	D 7466	16 mil	16 mil	16 mil	16 mil	16 mil	16 mil	16 mil	every 2 nd roll (2)
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties (min. ave.) (3) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	63 lb/in. 45 lb/in. 12% 100%	84 lb/in. 60 lb/in. 12% 100%	105 lb/in. 75 lb/in. 12% 100%	126 lb/in. 90 lb/in. 12% 100%	168 lb/in. 120 lb/in. 12% 100%	210 lb/in. 150 lb/in. 12% 100%	252 lb/in. 180 lb/in. 12% 100%	20,000 lb
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	45 lb	60 lb	75 lb	90 lb	120 lb	150 lb	180 lb	45,000 lb
Stress Crack Resistance (4)	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 (5)	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	20,000 lb
Carbon Black Dispersion	D 5596	note (6)	note (6)	note (6)	note (6)	note (6)	note (6)	note (6)	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) (7) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	200,000 lb
Oven Aging at 85°C (7), (8) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	per each formulation
UV Resistance (9) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (11)	D 7238 D 3895 D 5885	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	per each formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 14 mils, and lowest individual reading must be ≥ 12 mils; also see Note 6.

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

Yield elongation is calculated using a gage length of 1.3 inches

Break elongation is calculated using a gage length of 2.0 inches

(4) P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.

The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(5) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

9 in Categories 1 or 2 and 1 in Category 3

(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) (1)	D 7466	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	every 2 nd roll (2)
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) (3) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	11 kN/m 8 kN/m 12% 100%	15 kN/m 10 kN/m 12% 100%	18 kN/m 13 kN/m 12% 100%	22 kN/m 16 kN/m 12% 100%	29 kN/m 21 kN/m 12% 100%	37 kN/m 26 kN/m 12% 100%	44 kN/m 32 kN/m 12% 100%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	200N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance (4)	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 (5)	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	9,000 kg
Carbon Black Dispersion	D 5596	note (6)	note (6)	note (6)	note (6)	note (6)	note (6)	note (6)	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (7) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	90,000 kg
Oven Aging at 85°C (7), (8) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	per each formulation
UV Resistance (9) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (11)	D 7238 D 3895 D 5885	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	per each formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 0.35 mm, and lowest individual reading must be ≥ 0.30 mm; also see Note 6.

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

Yield elongation is calculated using a gage length of 33 mm

Break elongation is calculated using a gage length of 50 mm

(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.

The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(5) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

9 in Categories 1 or 2 and 1 in Category 3

(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

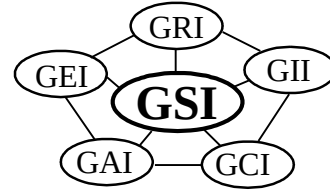
**Adoption and Revision Schedule
for
HDPE Specification per GRI-GM13**

“Test Methods, Test Properties, Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”

- Adopted: June 17, 1997
- Revision 1: November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
- Revision 2: April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: “(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)” and to Note (4) in the property tables.
- Revision 3: June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
- Revision 4: December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to “strength” and “elongation”.
- Revision 5: May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
- Revision 6: June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
- Revision 7: February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
- Revision 8: Removed recommended warranty from specification.
- Revision 9: June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
- Revision 10: April 11, 2011: Added alternative carbon black content test methods
- Revision 11: December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
- Revision 12: November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).

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Original: February 28, 2002
Revision 8: February 12, 2015
Revision schedule is on pg. 13

GRI Test Method GM19*

Standard Specification for

Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification addresses the required seam strength and related properties of thermally bonded polyolefin geomembranes; in particular, high density polyethylene (HDPE), linear low density polyethylene both nonreinforced (LLDPE) and scrim reinforced (LLDPE-R) and flexible polypropylene both nonreinforced (fPP) and scrim reinforced (fPP-R).

1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.

Note 1: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 5-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

Note 2: Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

- 1.4 This specification does not suggest a specific distance between destructive seam samples to be taken in the field, i.e., the sampling interval. A separate GRI Standard Practice is focused on this issue, see GRI-GM29.
- 1.5 This specification is only applicable to laboratory testing.
- 1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards

- D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
- D7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method

2.2 EPA Standards

- EPA 600/2.88/052 (NTIS PB-89-129670)
Lining of Waste Containment and Other Containment Facilities

2.3 GRI Standards

- GM13 Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
- GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
- GM17 Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes
- GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes
- GM20 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts
- GM25 Test Property and Testing Frequency for Scrim Reinforced Linear Low Density Polyethylene Geomembranes
- GM29 Practice for Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and Nondestructive Testing

3. Definition

- 3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.
- 3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams.
- 3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.
- 3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.
- 3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A depreciated method called “extrusion flat” seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

4. Significance and Use

- 4.1 The various methods of field fabrication of seams in polyolefin geomembranes are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field fabricated seams are sampled and laboratory tested in shear and peel. A separate GRI standard, GRI-GM29 (DRAFT), provides guidance as to the spacing that destructive samples should be taken in typical field installation projects.

5. Sample and Specimen Preparation

- 5.1 The spacing for taking field seam samples for destructive testing is provided in GRI-GM29 (DRAFT), a standard-of-practice. The process describes a progression from the most restrictive interval of 1 per 500 feet (1 per 150 m) to the complete use and reliance of the electrical leak location survey (ELLS) method. Intermediate between these extremes are variations depending upon the installers experience and performance.
- 5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.
- 5.3 The individual test specimens taken from the field seam samples are to be tested according to the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP, and ASTM D751 (modified to a 150 mm + seam width gage length) for fPP-R. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

6. Assessment of Seam Test Results

- 6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of four out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, five out five specimens should meet the shear percent elongation, calculated as follows, and exceed the values given in Tables 1(a) and 1(b):

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L_o = original average length (usually 1.0 in. or 25 mm)

Note 3: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b) for all five out of five specimens. The value shall be based on

the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_0}(100) \quad (2)$$

where

S = separation (%)

A = average area of separation, or incursion (in² or mm²)

A₀ = original bonding area (in² or mm²)

Note 4: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2

Exception: AD-WLD (unless strength is achieved)

Note 5: Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

6.2 LLDPE seams – For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) through 2(d). All five out of five should meet the shear elongation requirement.

$$E = \frac{L}{L_0}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L_o = original average length (usually 1.0 in. or 25 mm)

Note 3 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as “not applicable” in Tables 2 (c) and (d).

For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) through 2(d). All five out of five specimens shall meet the peel separation value. The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_0}(100) \quad (2)$$

where

S = separation (%)

A = average depth of separation, or incursion (in.² or mm²)

A₀ = original bonding distance (in.² or mm²)

Note 4 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2

Exception: AD-WLD (unless strength is achieved)

Note 5 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

- 6.3 fPP Seams – For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in shear should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation on the unreinforced specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the shear elongation requirement.

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L_o = original gauge length (usually 1.0 in. or 25 mm)

Note 3 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as “not applicable” in Tables 3(a) and 3(b).

For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are grab tests. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the peel separation value. The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation in (%)

A = average depth of separation, or incursion (in.² or mm²)

A_o = original bonding distance (in.² or mm²)

Note 4 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2

Exception: AD-WLD (unless strength is achieved)

Note 5 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

7. Retest and Rejection

- 7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

8. Certification

- 8.1 Upon request of the construction quality assurance officer or certification engineer, an installer's certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.

Table 1(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured**
High Density Polyethylene (HDPE) Geomembranes (**English Units**)

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams ⁽¹⁾							
shear strength ⁽²⁾ , lb/in.	57	80	100	120	160	200	240
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	45	60	76	91	121	151	181
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength ⁽²⁾ , lb/in.	57	80	100	120	160	200	240
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	39	52	65	78	104	130	156
peel separation, %	25	25	25	25	25	25	25

Notes for Tables 1(a) and 1(b):

1. Also for hot air and ultrasonic seaming methods
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured**
High Density Polyethylene (HDPE) Geomembranes (**S.I. Units**)

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams ⁽¹⁾							
shear strength ⁽²⁾ , N/25 mm.	250	350	438	525	701	876	1050
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	197	263	333	398	530	661	793
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength ⁽²⁾ , N/25 mm	250	350	438	525	701	876	1050
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	170	225	285	340	455	570	680
peel separation, %	25	25	25	25	25	25	25

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (English Units)

Geomembrane Nominal Thickness	20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams ⁽¹⁾								
shear strength ⁽²⁾ , lb/in.	30	45	60	75	90	120	150	180
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	25	38	50	63	75	100	125	150
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength ⁽²⁾ , lb/in.	30	45	60	75	90	120	150	180
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	22	34	44	57	66	88	114	136
peel separation, %	25	25	25	25	25	25	25	25

Notes for Tables 2(a) and 2(b):

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 2(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams ⁽¹⁾								
shear strength ⁽²⁾ , N/25 mm	131	197	263	328	394	525	657	788
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	109	166	219	276	328	438	547	657
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength ⁽²⁾ , N/25 mm	131	197	263	328	394	525	657	788
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	95	150	190	250	290	385	500	595
peel separation, %	25	25	25	25	25	25	25	25

Table 2(c) – Seam Strength and Related Properties of Thermally Bonded **Scrim Reinforced** Linear Low Density Polyethylene (LLDPE-R) Geomembranes (English Units)

Geomembrane Nominal Thickness	36 mil ⁽⁴⁾	45 mil ⁽⁴⁾
Hot Wedge Seams ⁽¹⁾		
shear strength ⁽²⁾ , lb	200	200
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , lb	20	20
peel separation, %	n/a	n/a
Extrusion Fillet Seams		
shear strength ⁽²⁾ , lb	200	200
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , lb	20	20
peel separation, %	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 2(d) – Seam Strength and Related Properties of Thermally Bonded **Scrim Reinforced** Linear Low Density Polyethylene (LLDPE-R) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	36 mil ⁽⁴⁾	45 mil ⁽⁴⁾
Hot Wedge Seams ⁽¹⁾		
shear strength ⁽²⁾ , N	890	890
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , N	90	90
peel separation, %	n/a	n/a
Extrusion Fillet Seams		
shear strength ⁽²⁾ , N	890	890
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , N	90	90
peel separation, %	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded **Nonreinforced and Scrim Reinforced** Flexible Polypropylene (fPP) Geomembranes (English Units)

Geomembrane Nominal Thickness	30 mil-NR	40 mil-NR	36 mil-R ⁽⁴⁾	45 mil-R ⁽⁴⁾
Hot Wedge Seams ⁽¹⁾				
shear strength ⁽²⁾ , lb/in. (NR); lb (R)	25	30	200	200
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength ⁽²⁾ , lb/in. (NR); lb (R)	25	30	200	200
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a

1. Also for hot air and ultrasonic seaming methods

2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values

3. Elongation measurements should be omitted for field testing

4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded **Nonreinforced and Scrim Reinforced** Flexible Polypropylene (fPP) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.75 mm-NR	1.0 mm-NR	0.91 mm-R ⁽⁴⁾	1.14 mm-R ⁽⁴⁾
Hot Wedge Seams ⁽¹⁾				
shear strength ⁽²⁾ , N/25 mm (NR); N (R)	110	130	890	890
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength ⁽²⁾ , N/25 mm (NR); N (R)	110	130	890	890
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a

1. Also for hot air and ultrasonic seaming methods

2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values

3. Elongation measurements should be omitted for field testing

4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

**Adoption and Revision Schedule
for
Seam Specification per GRI-GM19**

“Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes”

Adopted: February 18, 2002

Revision 1: May 15, 2003; Increased selected shear and peel test requirements, per the following:

Material	Test	Seam Type	Current GM19	Proposed GM19	Difference
HDPE	Shear	Hot Wedge Extrusion	95% yield 95% yield	95% yield 95% yield	no change no change
	Peel	Hot Wedge Extrusion	62% yield 62% yield	72% yield 62% yield	16% increase no change
LLDPE	Shear	Hot Wedge Extrusion	1300 psi break 1300 psi break	1500 psi break 1500 psi break	15% increase 15% increase
	Peel	Hot Wedge Extrusion	1100 psi break 1100 psi break	1250 psi break 1100 psi break	14% increase no change

Revision 2: January 28, 2005; added Note 6 (in three locations) stating that incursion is measured on an area basis and not depth as in ASTM D6392.

Revision 3: June 4, 2010; Removed Note 6 on peel incursion since ASTM D6392 (2008) now uses area of incursion whereas previously they used linear length of incursion. Thus ASTM is now in agreement with GM19 in this regard.

Revision 4: November 15, 2010; Added Note 6 (in three locations) stating what separation-in-plane (SIP) is, and is not, and that it is acceptable if the required strength, shear elongation and peel separation criteria are met.

Revision 5: July 12, 2011; AD1 and AD2 breaks are now unacceptable even if strength is achieved.

Revision 6: October 3, 2011; Added LLDPE-R to the various geomembrane types, in particular, Tables 2(c) and 2(d) and made editorial changes.

Revision 7: November 3, 2013; clarified issues of 4 out of 5 passing strength and 5 out of 5 passing locus-of-break, shear elongation and peel separation.

Revision 8: February 12, 2015; upgraded standards and terminology

APPENDIX C

CQA PROGRAMME TABLES

APPENDIX C

CQA PROGRAMME TABLES

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CQA PROGRAMME

FORMATION LAYER (CUT, FILL & FINAL SURFACE) 1

MATERIAL ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Engineered Fill	As required	Visual Inspection	Suitable material won from excavation for the Valley Cell Methods in accordance with Contractor's method statement and Specification	Verbal approvals	Removal of non-compliant materials from the works; use compliant materials. Record problem and solution on Daily Diary CQA Forms 1 & 3. Revision of method and or equipment used to be compliant
Surface elevation and gradient	As required	Liaison with surveyor	Compliance with design drawings. Surface level + 0mm; -50mm	Check Contractor's survey against Design Drawing. Release by completion of CQA Form 5 to Contractor. Prepare CQA Drawings 1 & 3	Supervise alteration of contours as necessary. Record problem and solution on Daily Diary CQA Forms 1 & 3
Extent of area prepared	As required	Liaison with surveyor	Compliance with design drawings. Surface level + 0mm; -50mm	Mark extent on copy of Design Drawing. Release by completion of CQA Form 5 to Contractor	Supervise alternation as necessary. Record problem and solution on Daily Diary CQA Forms 1 & 3
Formation fitness	As required	Visual Inspection Undrained shear strength on cohesive surfaces	No soft spots/areas Minimal rutting and damage caused by plant operations Hand vane tests on nominal 10m grid pattern – min shear strength 45kPa	Release by completion of CQA Form 5 to Contractor	Supervise excavations replacement and compaction in accordance with Specification. Record problem and solution

CQA PROGRAMME

FORMATION LAYER (CUT, FILL & FINAL SURFACE) 2

MATERIAL ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDATION
Remediation of cohesive Engineered Fill	As required after non compliant shear strength test results	Visual inspection Retested undrained shear strength	Area with 12.5m radius surrounding failed shear vane test to be reworked and retested - min shear strength 45kPa	Verbal approvals	Agree most effective course of action with the Contractor – either rework again or remove failing material and replace with compliant material. Inform Contractor of non-compliance in writing; record on CQA Forms 1 & 3.
Surface	As required	Visual inspection	Contractor to have proof rolled all formation surfaces prior to placement of clay liner. No vegetation, protruding gravel/cobbles > 20mm diameter. No soft spots	Verbal approvals	Supervise removal and replacement. Record problem and solution on Daily Diary CQA Forms 1 & 3
Surface condition	Ongoing but particularly at daily start up	Visual inspection	No desiccation cracks deeper than 12mm; no swelling or heaving	No action unless non-compliant. Release by completion of CQA Form 5 to Contractor	Inform Contractor of non-compliance in writing; record on CQA Forms 1 & 3.
Top of formation survey – cell base, perimeter slopes and bunds	Pre-clay liner construction	Electronic survey by Contractor	Survey points to be taken on notional grid set out in Specification. Results to be handed to CQA Engineer within 48hrs. Locally deepened for leachate chamber and monitoring points	TerraConsult CAD department to check survey compliant. Contractor's survey to be assessed with check survey for accuracy and survey tolerance. Prepare CQA Drawing 3. Send results to the EA as soon as ready	Inform Contractor of non-compliance in writing; record on CQA Forms 1 & 3. Contractor to undertake second survey or partial survey as appropriate.
Condition of existing cell lining system	When temp cap materials removed from cell edge	Visual inspection	No visible damage	Record length of cell edge inspected in daily diary; take photo of any damage and record damage	Discuss appropriate repairs with the Client and agree with the CQA Engineer and NRW.
Decommissioning of Cell 1 South Riser Pipe	When temp cap materials removed from cell edge	Visual inspection	Correct pipe end welded to the cut-back pipe. Waste placed as cover.	Verbal approvals. No action unless non-compliant. Record in daily diary.	Inform Contractor of non-compliance in writing; record on CQA Forms 1 & 3.

CQA PROGRAMME

VENEER INTERFACE SHEAR STRENGTHS

MATERIAL ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
<u>Lining system interfaces</u> • Geocomposite Drainage Layer / Waste Cover Soils • Engineered Clay / GCL • GCL / FML • FML / Protective Geotextile • Protective Geotextile / Leachate Drainage Aggregate	Two suites of tests at three pressures (50, 100 and 400 Kpa) on each interface	Large scale shear box test.	Results to verify and confirm the assumed results in the Stability Risk Assessment	Written Approval by Geotechnical Engineer	

CQA PROGRAMME
PREPARATORY EARTHWORKS
ANCHOR TRENCHES

MATERIAL/ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Position / location	Ongoing during the works	Visual monitoring	Check compliance with design drawings	Verbal approval; record on CQA Form 1	Discuss matters with Contractor and CQA Engineer and agree remediation measures. Record problem and solution on Daily Diary CQA Forms 1 & 3.
Shape	Ongoing during the works	Visual monitoring	Check compliance with design drawings – rounded edges achieved to inside edge	Verbal approval; record on CQA Form 1	Contractor to re-work the edge to be compliant with the Specification. Record problem and solution on Daily Diary CQA Forms 1 & 3.
FML installation	Ongoing during the works	Visual monitoring	Check compliance with design drawings – FML to be installed to the back edge of the trench Panels temporarily & securely anchored within the trench	Verbal approval; record on CQA Form 1	Contractor to undertake remediation work to ensure compliance with the Specification. Record problem and solution on Daily Diary CQA Forms 1 & 3.
Backfill	Ongoing during the works	Visual monitoring	Check compliance with the Specification	Verbal approval; record on CQA Form 1	Contractor to undertake remediation work to ensure compliance with the Specification. Record problem and solution on Daily Diary CQA Forms 1 & 3.

CQA PROGRAMME

CLAY LINER SOURCE EVALUATION 1

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Source evaluation test results	Prior to use on site	CQA Engineer then EA review of information provided	Suite of tests and results meet the requirements of the Specification	Written acceptance to Contractor	Find alternative source and test for compliance
Source Testing	Prior to use on site	Minimum number of suites of classification tests to be as per Table 5 of the EA's LFE4 guidance or as otherwise agreed with the NRW Tests as set out below	Ensure and confirm that the material proposed to form the clay liner is acceptable	Written acceptance to Contractor Provide test results to the EA	Find alternative source and test for compliance with Specification
Natural Moisture Content	1/1500m3 (min. 5)	BS 1377 Part 2 Method 3		Full records.	
Plasticity Index	1/1500m3 (min. 5)	BS 1377 Part 2 Method 5	Liquid limit not to exceed 90%. Plasticity index to be between 10% and 65%	Full records.	
Particle Density	1/5000m3 (min 3)	Particle density BS 1377 Part 2 Method 8	Record result and verify with previous results. Check against value used to derive air voids lines.	Full records .	
Particle size distribution	1/1500m3 (min. 5)	BS 1377 Part 2 Method 9.2 & 9.4	Fines content to be $\geq 20\%$ Clay content to be $\geq 8\%$	Full records.	

CQA PROGRAMME

CLAY LINER SOURCE EVALUATION 2

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Organic content	(test only if likely to be present) Test at interval of 1/1000m ³ .	BS 1377 Part 3 Method 3	Organic content to be <10% by weight	Full records	
Compaction – Moisture / Density Relationship	1/5000m ³ (min 3)	BS 1377 Part 4 Method 3.3/3.4 – 2.5kg compaction Include shear vanes at each increment of the compaction test.	Not applicable	Use results to prepare, source compaction graph	
Multistage quick undrained shear strength	1/5000m ³ (min 1) One test means a set of three individual specimens tested at different cell pressures.	BS 1377 Part 7 Method 7			
Hydraulic Conductivity	6/5000m ³ (min 6)	BS 1377 Part 6 Method 6	Permeability $\leq 1 \times 10^{-8}$ m/s	Full records	

CQA PROGRAMME

CLAY LINER COMPACTION TRIALS 1

ITEM	PROPERTY	TEST	TEST RATE	COMPLIANCE	REMEDICATION
Trial numbers	N/A	N/A	N/A	1nr compaction trial for each source and or change in compaction plant and or change in methods	Further trials as necessary
Trial Liner dimensions	Area and location – base and sidewall trials to be carried out	Visual inspection	N/A	Refer to Specification, Record in CQA Diary	Extend as necessary
Material	Record source. Record method of transportation and placement	N/A	N/A	Record in CQA Diary	
Plant	Record make and model of plant, record operating speed and No. of passes	N/A	N/A	Record in CQA Diary	
Layers	Interface adhesion (Full Photographic Record)	Visual inspection of interface adhesion by destructive excavation of trial liner	n/a	Minimum 3nr layers; first layer to be sacrificial (not tested) Adequate layer interface adhesion	Revise method used to key layers together and retest
Representative testing	Depth / position of sampling and or testing within clay layer	Visual inspection	N/A	Testing and sampling to be representative of the full depth profile of each layer.	Retest / resample, Record position of failures for inclusion in CQA Validation report
Nuclear Density Meter	Moisture content and Dry Density Determination	BS1377 Part 9 Method 2.5	Min. 4 No. per layer on base and on sidewall	≤ 5% air voids Min. moisture content to = plastic limit; max. moisture content parameters – to be confirmed Record on CQA Form 6	Additional compactive effort.

CQA PROGRAMME

CLAY LINER COMPACTION TRIALS 2

ITEM	PROPERTY	TEST	TEST RATE	COMPLIANCE	REMEDICATION
Core Cutter	Moisture Content and Dry Density Determination	BS1377 Part 9 Method 2.4	Min. 4 No. per layer on base and on sidewall	As above Record on CQA Form 7	Additional compactive effort.
Permeability	Constant Head Permeability in a triaxial cell	BS 1377 Part 6 Method 6	Min. 2 No. per layer on base and min. 1 No. per layer on sidewall	Less than or equal to 1×10^{-8} m/sec	Restart then record problem and solution
Plasticity Index		BS 1377 Part 2 Method 5	Min. 2 No. per layer on base and min. 1 No. per layer on sidewall	Liquid limit not to exceed 90%. Plasticity index to be between 10% and 65% Full records.	Instruct retesting and/or confirm unacceptability. Record problem and solution on Daily Diary CQA Forms 1 and 3.
Particle Density		Particle density BS 1377 Part 2 Method 8	Min. 2 No. per layer on base and min. 1 No. per layer on sidewall	Record result and verify with previous results. Check against value used to derive air voids lines on standard graph Full records .	Instruct retesting and/or confirm unacceptability. Record problem and solution on Daily Diary CQA Forms 1 and 3.
Particle size distribution		BS 1377 Part 2 Method 9.2	Min. 2 No. per layer on base and min. 1 No. per layer on sidewall	Fines content to be $\geq 20\%$ Clay content to be $\geq 8\%$ Full records.	Instruct retesting and/or confirm unacceptability. Record problem and solution on Daily Diary CQA Forms 1 and 3.
Undrained shear strength	Undrained shear strength	Hand shear vane BS 1377 Part 9 Method 4.4	Min. 4 No. per layer on base and on sidewall	≥ 50 kPa on base; 50kPa on sidewall Full records. Record on CQA Form 8	Retest and/or remove failed area. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Trial to be left in place?	N/A	N/A	N/A	If all test results = compliant then trial remains in place If any test fails then trial to be removed	Further trial to be carried out. Reuse trial material for further trials or clay liner.
Survey	Measurements to be taken to locate the trial area and define its extent.	Electronic survey	All trial liners	Include survey results on CQA Drawing 10	Remedial action as appropriate. Record the problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

CLAY LINER TESTING 1

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Contractor's Method Statement	Pre-start of the Works	n/a	Acceptable, adequate and complies with the Specification requirements. Reflects the results of the trial liner.	Written acceptance by CQA Engineer	Contractor to redraft and resubmit for review.
Plant and methods used	At start up and continuous during construction works	Visual inspection	Plant and methods in accordance with Contractor's method statement and results of trial liner.	No action unless non-compliant Inform Contractor that works may proceed.	Inform Contractor in writing and ensure that correct plant and methods used. Instruct replacement / reworking of area of liner constructed using non-compliant plant / methods. Record problem and solution on Daily Diary CQA Forms 1 & 3
Clay Liner Subgrade	During construction works	Visual inspection; hand shear vane tests on cohesive surfaces; review of subgrade surveys	Elevation, gradient, firmness and quality of surface to be compliant with the Specification 45kPa undrained shear strength	Verbal acceptance Contractor's survey to be assessed with check survey for accuracy and survey tolerance. Release by completion of CQA Form 5 to Contractor Prepare CQA Drawing 3. Send results to the EA as soon as ready	Rework and repair as per the requirements of the Specification Record problem and solution on Daily Diary CQA Forms 1 & 3
Placed layer thickness	During construction works	Visual inspection	Clay placed in separate layers such that when compacted max. thickness no greater than nominal 250mm or otherwise agreed from trial liner results.	No action unless non-compliant	Inform Contractor verbally and ensure that correct thickness applied. Instruct replacement / reworking of area of liner of non-compliant thickness. Record problem and solution on Daily Diary CQA Forms 1 & 3

CQA PROGRAMME

CLAY LINER TESTING 2

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Scarification of inter-layer surface	During construction works	Visual inspection	Surface of layer to be scarified to nominal depth of 25mm before next layer placed.	No action unless non-compliant	Inform Contractor verbally and ensure that surface is scarified. Instruct replacement / reworking of area of liner as appropriate. Record problem and solution on Daily Diary CQA Forms 1 & 3
Stone/clod size of clay liner material	During placement	Visual inspection	$\leq 125\text{mm}$ well dispersed through clay liner mass	No action unless non-compliance.	Remove outsized clods and or mix clay to disperse clods through clay liner material. Record problem and solution on Daily Diary Form 1 and CQA Form 3.
Total Liner Thickness – Cell Base, Sideslopes & Sumps for leachate Chamber & Monitoring Points	Measurements taken in accordance with the Specification	Electronic survey	○ Basal liner minimum 500mm (+2x survey tolerance) thick normal to surface. ○ Sidewall liner minimum 500mm (+2x survey tolerance) thick normal to surface. See Specification, Table 4.1	Prepare CQA Drawing 9 by reference to CQA Drawings 3 and 6. Mark extent on copy of Design Drawing.	Instruct and supervise appropriate remedial works Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Representative testing	Depth / position of sampling and or testing within clay layer	Visual inspection	n/a	Testing and sampling to be representative of the full depth profile of each layer.	Retest / resample
Moisture content and Dry Density Determination	Tests to be carried out on a 20m grid per layer (1/100m ³)	Nuclear Density Gauge BS 1377 Part 9 Method 2.5	$\leq 5\%$ air voids; moisture content parameters to be confirmed from source testing	Full records – results to fall within target window. Record on CQA Form 6.	Instruct retesting and/or removal of layer. Record problem and solution on Daily Diary CQA Form 1 and Form 3.
Moisture content and Dry Density Determination	Field tests to be carried out at 1 per 5nr NDG tests	Core cutter BS 1377 Part 9 Method 2.4 Microwave oven method.	$\leq 5\%$ air voids moisture content parameters to be confirmed from source testing	Full records – results to fall within target window. Record on CQA Form 7.	Instruct retesting and/or removal of layer. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.

CQA PROGRAMME

CLAY LINER TESTING 3

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Undrained shear strength	Tests to be carried out on a 20m grid per layer (1/100m3)	Hand shear vane BS 1377 Part 9 Method 4.4	$\geq 50\text{kPa}$ on base; $\geq 50\text{kPa}$ on sidewall	Full records. Record on CQA Form 8.	Retest and/or remove failed area. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Permeability of Liner	Samples taken on a 45m grid on each layer (1 per 400m3)	Permeability on undisturbed core BS 1377 Part 6 Method 6	Permeability $< 1 \times 10^{-8}\text{m/s}$	Full records.	Instruct retesting and/or removal of layer. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Plasticity Index of clay liner material	Samples taken on a 30m grid on each layer (1 per 200m3)	BS 1377 Part 2 Method 5	Liquid limit not to exceed 90%. Plasticity index to be between 10% and 65%	Full records.	Instruct retesting and/or removal of layer. Record problem and solution on Daily Diary CQA Forms 1 and 3.
Particle Density of clay liner material	Samples taken on a 45m grid on each layer (1 per 405m3)	Particle density BS 1377 Part 2 Method 8	Record result and verify with previous results. Check against value used to derive air voids lines.	Full records .	Instruct retesting and/or removal of layer. Record problem and solution on Daily Diary CQA Forms 1 and 3.
Particle size distribution of clay liner material	Samples taken on a 45m grid on each layer (1 per 400m3)	BS 1377 Part 2 Method 9.2	Fines content to be $\geq 20\%$ Clay content to be $\geq 8\%$	Full records.	Instruct retesting and/or removal of layer. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Location & Number of In-situ Test & Sample Points	Approximate locations to be recorded by CQA Eng.	n/a	All points picked up and plotted on relevant layer CQA drawing Number and frequency of samples and tests in accordance with this CQA Plan	Prepare CQA Drawing 10 by reference to CQA Engineer's drawings prepared on site	Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Ongoing calibration of Nuclear Density Gauge	Constant review by CQA Engineer	Nuclear Density Gauge BS 1377 Part 9 Method 2.5	Keep existing calibration factors if no significant change as defined by the Project Manager.	Change factors on NDG record forms from the date of the change forwards; no retrospective changes. Full records of recalibration.	Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.

CQA PROGRAMME

CLAY LINER TESTING 4

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Clay liner panel layout	Ongoing during clay liner construction	n/a	n/a	Full record of location, extent and dimensions of each panel relevant to each layer to be kept in notebook and on CQA Drawing 10. Record method used to connect the panels.	Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Clay liner panel connections	During connection works	Visual inspection	Stepped joint between adjacent panels	All panel joints plotted on relevant layer CQA drawing Prepare CQA Drawing 10 by reference to CQA Engineer's drawings prepared on site	Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Sealing of clay liner layer surface	At the end of each work shift	Visual inspection	Smooth finish and sealed up to prevent water ingress	Verbal approval to Contractor	Reroll as necessary using smooth roller
CQA test location perforations	During CQA testing and sampling	N/A	All perforations to be backfilled with clay and tamped in thin layers by use of hand tools	Visual inspection that all perforations backfilled	Backfill as necessary

CQA PROGRAMME

CLAY LINER TESTING 5

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Final Clay Liner Surface	Prior to the installation of the GCL	Visual inspection	Surface to be even and stable, no standing water, no sharp or sudden changes in grade and free of track marks, roller marks, protrusions, hollows, sharp objects and soft spots. Surface to be protected from drying, flood and freezing in accordance with the Specification	Written acceptance using CQA Form 10 Acceptance to be withdrawn if surface deteriorates before FML placed over any one area.	Withdraw acceptance. Instruct removal or reworking of non-compliant area. Re-inspect and reissue acceptance in writing if appropriate. Record problem and solution on Daily Diary CQA Forms 1 and 3.

CQA PROGRAMME

CLAY LINER TESTING 6

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Top of Clay Liner Survey	Pre-geosynthetic layer installation	Electronic survey carried out by Contractor, – see specification section 2.4	Survey points to be taken on top surface of clay liner in accordance with the Specification to form top survey for layer thickness assessments. Results to be handed to CQA Engineer within 48hrs. Locally deepened for leachate chamber and monitoring points	TerraConsult CAD department to check survey compliant. Contractor's survey to be assessed with check survey for accuracy and survey tolerance. Send results to the EA as soon as ready Prepare CQA Drawing 6.	Inform Contractor of non-compliance in writing; record on CQA Forms 1 & 3. Contractor to undertake second survey or partial survey as appropriate.
Top of Clay Liner Survey	Pre-geosynthetic layer installation	Electronic survey carried out by Contractor, – see specification section 2.4	Survey points to be taken on top surface of clay liner in accordance with the Specification to form top survey for layer thickness assessments. Results to be handed to CQA Engineer within 48hrs. Locally deepened for leachate chamber and monitoring points	TerraConsult CAD department to check survey compliant. Contractor's survey to be assessed with check survey for accuracy and survey tolerance. Send results to the EA as soon as ready Prepare CQA Drawing 6.	Inform Contractor of non-compliance in writing; record on CQA Forms 1 & 3. Contractor to undertake second survey or partial survey as appropriate.

CQA PROGRAMME

GEOSYNTHETIC CLAY LINER (GCL) 1

MATERIAL/ITEM	INTERVAL	CQA REQUIREMENTS	ACCEPTANCE CRITERIA	COMPLIANCE	REMEDATION
CQA Programme and Method Statement	Pre-commencement	Review CQA programme and installation method statement provided by contractor	Comprehensive, Suitable, Adequate, & Compliance with clients requirements	Written approval File documents	Liaison with contractor/regulator for further information and/or rectification
Panel layout	Pre-commencement	Review scaled drawing supplied by contractor	Minimise seaming. Correct panel orientation	Written approval File documents	Liaison with contractor
Pre Start Meeting	Pre-commencement	Attend pre-start meeting	Agree programme of works and any other matters arising before works commence	N/A	N/A
Roll Delivery	Per batch to site	Review/record roll details and factory QC test results / data sheets	Details match rolls; all rolls have a QC data sheet. Manufacturers QC sheets conform with specification – Table 5.2. Data supplied for all parameters listed in specification / CQA Plan	Approve rolls/batch for use on site. Complete CQA Form 9 and file records. Ensure all QC Data sheets have all appropriate test results.	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3. Prevent use of roll until full results and or provenance established.
Roll Delivery	Per batch to site	Supervise unloading.	No damage to rolls.	Approve rolls/batch for use on site. Complete CQA Form 9 and file records	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Roll Delivery	Per batch to site	Visually inspect each roll for damage	No damage. .	Approve rolls/batch for use on site.	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Storage of rolls	Per batch	Visual inspection	Record lifting method used. Compliance of storage location and method with manufacturers recommendations and specification / CQA Plan. Rolls covered with waterproof tarpaulin	N/A	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3

CQA PROGRAMME

GCL 2

ITEM	PROPERTY	TEST	TEST RATE	COMPLIANCE	REMEDATION
Conformance Sampling	Supervise removal of conformance samples		1 sample per 2,500m ² Except permeability tested at 1 sample per 5000m ²	Record conformance samples on CQA Form 9.	Collect further samples. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Conformance Testing	Parameters detailed in Table 5.2 of the specification	Test methods are to match manufacturer's stated methods on QC data sheets	Each sample will have a complete suite of tests except for MPUA and free swell– see below.	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll
Additional conformance testing	Mass per unit area of both whole GCL and bentonite component of GCL tested separately	EN 965	1/500m ² for whole GCL 1/500m ² for bentonite component	MPUA of GCL $\geq 5,000\text{g/m}^2$ @ 15% moisture content MPUA of bentonite $\geq 4670\text{g/m}^2$ @ 15% moisture content	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll
Additional conformance testing	Free swell	EN 965	1/250m ²	To be confirmed by CQA Engineer when product specification known	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll
Conformance Testing – at the discretion of the CQA Engineer	Any one, selection or all of the above tests.	Test methods are to match manufacturer's stated methods on QC data sheets	At the discretion of the CQA Engineer to maintain quality control on materials being delivered.	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll

CQA PROGRAMME

GCL 3

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Subgrade (Clay Liner Surface)	Per panel	Visual inspection and measurements using a lath	In accordance with sub-grade criteria in Specification.	Records to be kept on CQA Form 10, to be signed. Withdraw approval if surface becomes non-compliant. Reissue after repair and compliance.	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Roll deployment	1 per roll	Visual inspection	Record method of deployment.	Record on CQA Form 11	Instruct removal of roll. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Roll deployment	1 per panel	Visual inspection	No defects/damage. Compliance with panel layout. Correct overlap. Correctly weighted down. Installed with the correct geotextile face up.	Record acceptance criteria as “passed” on CQA Form 11 Contractor’s meth stat and the Specification Record deployment layout on CQA Drawing 11	Instruct repair and/or rejection/remediation of sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
General installation	Ongoing during installation	Visual inspection	List of criteria for installer to comply with details in the Specification	No action unless installer is non-compliant.	Instruct repair and/or rejection / remediation of sheet and or seam. Records on CQA Forms 1 and 3
Environmental conditions	Per installation session	As per specification requirements / controls	Refer to Specification.	Record conditions acceptable on CQA Form 11.	Prevent deployment until conditions allow

CQA PROGRAMME

GCL 4

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
GCL hydration	Per panel deployed	Visual inspection – different colour compared to surrounding GCL or different thickness	Excessively hydrated GCL to be covered or replaced prior to deployment of further GCL.	Verbal approval	Repair by covering or replacement as appropriate
Roll overlap	Per seam margin	Visually inspect / measure sheet overlap	Compliant with criteria in Specification – min. 250mm; panel ends – min. 500mm No soil / deleterious materials within the overlap No wrinkles / fishmouths Upslope seam to overlap downslope seam No excessive hydration	Verbally approve welding.	Instruct remedial work. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Seaming – accessory bentonite	1 sample per 5 Panel ends or where a panel cut to shape if bentonite impregnated GCL used; include for 1 sample per 50m seam margins if non impregnated GCL used	Visually inspection Mass per unit length of bentonite powder	Accessory bentonite correctly positioned relative to sheet edge. Min. 0.5kg/lin. m of bentonite powder as powder weight if paste used	Verbally approve seaming. Record test results on CQA Form 12	Mark GCL. Instruct remediation. Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

GCL 5

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Repairs	As necessary	Supervise patch repairs and seaming	Repair meets relevant seam criteria	Record repair on CQA Form 13	Record problem and solution on CQA Forms 1 & 3.
Walkover survey	Pre cover	Visual inspection of HDPE liner installation.	All repairs completed and tested and OK. All fusion welds tested and OK. No further repairs required. No potentially damaging objects on liner.	Approve the placement of protective geotextile in writing to the Contractor .	Instruct remedial action as necessary. Record problem and solution on CQA Forms 1 & 3..
Survey	Pre cover	Supervision of survey of all panels, panel references, repair locations and extent of GCL including anchor trench location.	Pre placement of geomembrane	Preparation of as-installed layout plan as CQA Drawing 11	Record problem and solution on CQA Forms 1 & 3.
GCL covering	Ongoing	Visual inspection	All GCL covered by the end of each day / shift by materials allowed by the specification FML to be installed as soon as possible but prior to rain and or the end of the day.	Verbal approvals Written approval of acceptance of the GCL surface as a FML subgrade prior to deployment.	Excessively hydrated material to be replaced Record problem and solution on CQA Forms 1 & 3.
General design	Ongoing	Supervise: anchor trenches. Leachate chamber & monitoring points detail.	Ensure installed to design specification. Ensure backfilled in compliance with Specification.	Record verbal approval on Daily Diary CQA Form 1 as appropriate.	Instruct remedial works. Record problem and solution on CQA Forms 1 & 3.

HDPE LINER 1

MATERIAL/ITEM	INTERVAL	CQA REQUIREMENTS	ACCEPTANCE CRITERIA	COMPLIANCE	REMEDICATION
CQA Programme and Method Statement	Pre-commencement	Review CQA programme and installation method statement provided by contractor	Comprehensive, Suitable, Adequate, & Compliance with clients requirements	Written approval File documents	Liaison with contractor/regulator for further information and/or rectification
Panel layout	Pre-commencement	Review scaled drawing supplied by contractor	Minimise seaming. Correct panel orientation	Written approval File documents	Liaison with contractor
Contractors personnel	Pre-commencement	Review proposed site personnel CVs and BGA certificates	Suitable and relevant experience. Hold current accreditation with BGA.	Approve proposed personnel File documents	Liaise with contractor. Prevent installation carried out by non-accredited personnel.
Pre Start Meeting	Pre-commencement	Attend pre-start meeting	Agree programme of works and any other matters arising before works commence	N/A	N/A
Roll Delivery	Per batch to site	Review/record roll details and factory QC test results / data sheets	Details match rolls; all rolls have a QC data sheet. Manufacturers QC sheets conform with specification – Table 6.5. Data supplied for all parameters listed in specification	Approve rolls/batch for use on site. Complete CQA Form 9 and file records. Ensure all QC Data sheets have all appropriate test results.	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3. Prevent use of roll until full results and or provenance established.
Roll Delivery	Per batch to site	Supervise unloading.	No damage to rolls.	Approve rolls/batch for use on site. Complete CQA Form 9 and file records	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Roll Delivery	Per batch to site	Visually inspect each roll for damage and take random thickness measurements with micrometer	No damage. Compliance with manufacturer's specification.	Approve rolls/batch for use on site.	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Storage of rolls	Per batch	Visual inspection	Record lifting method used. Compliance of storage location and method with manufacturers recommendations and CQA Plan	N/A	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3

CQA PROGRAMME

HDPE LINER 2

ITEM	PROPERTY	TEST	TEST RATE	COMPLIANCE	REMEDICATION
HDPE Sampling	Supervise removal of conformance. samples of FML rolls		1 sample per 5,000m ² or every 5 rolls delivered whichever is the greatest number of tests. At least 1 additional sample to be tested if materials from different resin sources or manufacturing lines.	Record conformance samples on CQA Form 14.	Collect further samples. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Conformance Testing	Parameters detailed in Table 6.5 of the Specification	Test methods are to match manufacturer's stated methods on QC data sheets	Each sample will have a complete suite of tests. Stress crack resistance = 1 sample per 10,000m ² . If >1 resin source used then take at least 1 extra sample from each batch.	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll
Conformance Testing – at the discretion of the CQA Engineer	Any one, selection or all of the above tests.	Test methods are to match manufacturer's stated methods on QC data sheets which should conform with the specification	At the discretion of the CQA Engineer to maintain quality control on materials being delivered.	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll

CQA PROGRAMME

HDPE LINER 3

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDIATION
Subgrade	Per panel	Visual inspection	In accordance with sub-grade criteria in Specification.	Records to be kept on CQA Form 15, to be signed. Withdraw approval if surface becomes non-compliant. Reissue after repair and compliance.	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
HDPE roll deployment	1 per roll	Visual inspection	Record method of deployment. First 1m length of roll to be discarded	Record on CQA Form 16 Record deployment layout on CQA Drawing 12	Instruct removal of FMLI. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
HDPE roll deployment	1 per panel	Visual inspection	No defects/damage. Compliance with panel layout. Correct overlap. Correctly weighted down.	Record acceptance criteria as “passed” on CQA Form 16 Contractor’s meth stat and the Specification	Instruct repair and/or rejection/remediation of sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
HDPE roll deployment	1 measurement per 20m length of panel	Sheet thickness using micrometer	Refer to specification	Records to be kept on CQA Form 16	Retest. Reject sheet as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
General FML installation	Ongoing during FML installation	Visual inspection	List of criteria for installer to comply with details in the Specification such as temporary surcharge	No action unless installer is non-compliant.	Instruct repair and/or rejection / remediation of sheet and or seam. Records on CQA Forms 1 and 3
Environmental conditions	Per welding session	Visual inspection and use of Contractor’s measurements and records	Refer to Specification.	Records to be kept on CQA Forms 16 & 17.	Prevent welding until conditions allow or supervise trial

CQA PROGRAMME

HDPE LINER 4

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Trial seams	Pre-seaming or after machine shutdown of >0.5 hr or every 4 hrs or at change of welding temperature, speed or technician – all weld units	Inspection of qualitative destructive testing	Five samples – peel Five samples – shear Failure not in seam	Record acceptance criteria as “passed” on CQA Form 17.	As dictated by Specification and contractors Method Statement. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Seaming – general	Per seam margin	Visually inspect sheet margin	Compliant with criteria in Specification	Verbally approve welding.	Instruct remedial work and/or reject seam. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Seaming – Fusion welding (hot wedge)	Per seam margin	Visually inspect welding	Weld correctly positioned relative to sheet edge. Correct width of weld. Air channel present. Weld conditions same as for trial weld.	Verbally approve welding. Record conditions on CQA Form 18	Mark liner. Instruct remediation and/or rejection. Record problem and solution on CQA Forms 1 & 3.
Extrusion welding	All “T” seam connections	Visual inspection	All “T” seam connections covered with an extrusion weld to min. 200mm from “T” apex.	Non unless non compliant.	Record non compliance and repair / action taken on CQA Forms 16, 1 & 3.
Extrusion welding	Per weld run	Visual inspection	Area to be welded adequately buffed. Copper wire used. Adequate width of weld. Weld conditions same as for trial weld.	Verbally approve welding Record conditions on CQA Form 19	Mark liner. Instruct remediation and/or rejection. Record problem and solution on CQA Forms 1 & 3.
Qualitative destructive Testing Tab Samples	Start and end of each major seam	Peel and shear seam strength test	Failure must occur in sheet not in weld. Ensure both sides of the weld are tested under peel	Make records on CQA Form 18.	Instruct remediation and/or rejection. Record problem and solution on CQA Forms 1 & 3..

CQA PROGRAMME

HDPE LINER 5

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDIATION
Quantitative destructive Testing Laboratory	Fusion welds – min. frequency of 1 suite per 200m of seam length. Extrusion welds – min. frequency of 1 suite per 200m of seam length (with a minimum of 1 if total length of seam <200m) and 1 suite on every day in which 25m or more of seam is completed.	Seam strength (ASTM D6392) Thickness (ASTM D751)	Minimum peel and shear strength – refer to specification. Thickness: refer to specification	Approve weld lengths. Record sample on CQA Form 18	Relate to contractor's method statement and Specification. Record problem and solution on CQA Forms 1 & 3.
Non Destructive Testing Air Pressure Testing (APT)	Per hot wedge weld run	Supervise and approve contractor's testing	All hot wedge welds to be tested. Pressure to be between 2.0 bar (30psi, 205kPa) and 2.4 bar (35psi, 240kPa). No pressure loss in 1st minute and held without loss of > 10% pressure over 5 min.	Mark on sheet as tested and OK. Record test on CQA Form 20. Sign contractor's record form.	Mark on sheet. Full records to be made. Instruct retest and/or reweld. Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

HDPE LINER 6

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Non Destructive HVE (High Voltage Electrode) testing	Per extrusion weld	Supervise and approve contractors testing	Full length of weld tested at <1 m/min and <50mm from weld. No sparks.	Mark sheet as tested and OK. Record test on CQA Form 20. Sign contractor's record form.	Observe and supervise reweld and retest. Record problem and solution on CQA Forms 1 & 3.
Vacuum Box testing	Per extrusion weld	Supervise and approve contractors testing	Full length of weld tested. No air leaks.	Mark sheet as tested and OK. Record test on CQA Form 20. Sign contractor's record form.	Observe and supervise reweld and retest. Record problem and solution on CQA Forms 1 & 3.
Repairs	As necessary	Supervise welding and testing	Repair passes relevant seam criteria	Mark sheet as tested and OK. Record test on CQA Form 20. Sign contractors record form and complete CQA Form 21	Observe and supervise reweld and retest. Record problem and solution on CQA Forms 16, 1 & 3.
Walkover survey	Pre cover	Visual inspection of HDPE liner installation.	All repairs completed and tested and OK. All fusion welds tested and OK. No further repairs required. No potentially damaging objects on liner.	Provide verbal approval of the placement of protective geotextile.	Instruct remedial action as necessary. Record problem and solution on CQA Forms 17, 1 & 3..
Survey	Pre cover	Supervision of survey of all panels, panel references, different weld type, sample & repair locations and extent of HDPE liner including anchor trench location.	Pre placement of protective geotextile	Preparation of as-installed layout plan as CQA Drawing 12	Record problem and solution on CQA Forms 17, 1 & 3.
General design	Ongoing	Supervise: anchor trenches. Leachate chamber & monitoring points detail.	Ensure installed to design specification. Ensure backfilled in compliance with Specification.	Record verbal approval on Daily Diary CQA Form 1.	Instruct remedial works. Record problem and solution on CQA Forms 17, 1 & 3.

CQA PROGRAMME

PROTECTIVE GEOTEXTILE 1

MATERIAL/ITEM	INTERVAL	CQA REQUIREMENTS	ACCEPTANCE CRITERIA	COMPLIANCE	REMEDICATION
CQA Programme and Method Statement	Pre-commencement	Review CQA programme and installation method statement provided by contractor	Comprehensive, suitable, adequate, & compliance with Contract requirements	Written approval File documents	Liaison with contractor/regulator for further information and/or rectification
Suitability of product	Pre-delivery	Review proposed product specification against specification	Compliance with Specification	Written approval File documents	Liaise with contractor. Reject product as necessary. Review new product.
Suitability of product	Pre-delivery	Review Accelerated Cylinder Test Results	Compliance with EA Guidance (A METHODOLOGY FOR CYLINDER TESTING OF PROTECTORS FOR GEOMEMBRANES issued by the Environment Agency in April 2006)	Written approval File documents	Liaise with contractor. Reject product as necessary. Review new product.
Roll Delivery	Per batch to site	Review/record roll details and factory QC test results / data sheets	Product delivered correct. Details match rolls; all rolls covered by QC information. Manufacturers QC sheets conform with manufacturers specifications.	Approve rolls/batch for use on site. Complete CQA Form 22 and file records.	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3. Prevent use of roll until compliant data provided.
Roll Delivery	Per batch to site	Supervise unloading.	No damage to rolls. Record method of unloading.	Approve rolls/batch for use on site. Complete CQA Form 22 and file records	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Storage of rolls	Per batch	Visual inspection	Record lifting method used. Compliance of location and method of storage with manufacturers recommendations and specification	N/A	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3

CQA PROGRAMME

PROTECTIVE GEOTEXTILE 2

ITEM	PROPERTY	TEST	TEST RATE	COMPLIANCE	REMEDATION
Protective geotextile sampling	Supervise removal of conformance. samples from rolls	Samples for thickness under 2kPa & MPUA Samples for puncture resistance, cone drop, tensile properties	1 sample per 2,500m ² or 1 every batch whichever is the greatest number of tests. 1 sample per 6,000m ² or 1 every batch whichever is the greatest number of tests.	Values to be set by CQA Engineer following confirmation of product. Record conformance samples on CQA Form 22.	Collect further samples. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Conformance Testing	Parameters detailed in the Protection Geotextile table at section 7.2 of the Specification	Test methods are to match manufacturer's stated methods on QC data sheets	Each sample will have a complete suite of tests.	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3. Then if still failure reject roll

CQA PROGRAMME

PROTECTIVE GEOTEXTILE 3

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Subgrade (FML) surface	Per panel	Visual inspection	In accordance with sub-grade inspection criteria in Specification	No action unless non-compliant	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Roll deployment	1 per panel	Visual inspection	No defects/damage. Compliance with panel layout requirements. Correct overlap. Temporary surcharge used as necessary	Record acceptance criteria as “passed” on CQA Form 23 Record deployment layout on CQA Drawing 13 In accordance with specification	Instruct repair and/or rejection/remediation of sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
General geotextile installation	Ongoing during geotextile installation	Visual inspection	List of criteria for installer to comply with details in the Specification	No action unless installer is non-compliant.	Instruct repair and/or rejection/remediation of sheet and or seam. Record problem and solution on Daily Diary CQA Forms 1 and 3
Environmental conditions	Per welding session	Parameters as set out in specification	Acceptable conditions as defined in the specification	Record acceptance criteria as “passed” on CQA Form 23	Prevent welding until conditions allow.
Seaming – general	Per sheet margin	Visually inspect sheet margin	Aligned correctly. No wrinkles or crimps. Correct overlap. Seaming method compliant with installer’s method statement. Adequate adhesion.	Verbally approve welding.	Instruct remedial work and/or reject seam / sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Repairs	As necessary	Supervise seaming	Aligned correctly. No wrinkles or crimps. Correct overlap. Seaming method compliant with installer’s method statement. Adequate adhesion.	Verbally approve welding. Make records on CQA Form 24. Each repair to have a unique location reference number as for FML repairs.	Instruct remedial work and/or reject seam / sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.

CQA PROGRAMME

PROTECTIVE GEOTEXTILE 4

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Walkover survey	Pre cover	Visual inspection of geotextile installation.	All repairs completed and tested and OK. No further repairs required. No potentially damaging objects on geotextile.	Verbal approval of the placement of covering layer & leachate drainage stone subject to receipt and compliance of all Clay Liner test results.	Instruct remedial action as necessary. Record problem and solution on CQA Form 20 and CQA Forms 1 & 3.
Survey	Pre cover	Supervision of survey of all panels, panel references, seams, repair locations and extent of geotextile including anchor trench location.	Pre placement of covering layer	Preparation of as-installed layout plan as CQA Drawing 13	Record problem and solution on CQA Forms 1 & 3.
General design	Ongoing	Supervise: anchor trenches. Leachate extraction chamber detail.	Ensure installed to design specification. Ensure backfilled in compliance with Specification.	Record verbal approval on Daily Diary CQA Form 1 as appropriate.	Instruct remedial works. Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

LEACHATE DRAINAGE AGGREGATE 1

MATERIAL/ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Aggregate sources	Pre-delivery	Assess suitability of aggregates for intended use from Spec. using test data provided by Contractor.	Meets Specification requirements for all relevant parameters.	Written approval for use	Contractor to find compliant source. Contractor to provide full suite of test data.
Compliance Testing	2 samples from first load, thereafter 1 sample per 500m ³ laid	Each sample shall be tested for the following: Grading – BS1377, Part 2 10% fines value – BS812 Part 111 (soaked condition)	Refer to section 9.2.1 in Spec: >100kN Correct grading distribution for the grade of stone used	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3.
Compliance Testing	3 samples from each source taken at random from as-placed material	Permeability testing – HA 41/90 Design Manual for Roads & Bridges Vol 4 section 2	$\geq 1 \times 10^{-2}$ m/s	To be confirmed by CQA Engineer comparing the results against specification.	Retesting of failed samples Record problem and solution on CQA Forms 1 & 3.
Aggregate Placement Method Statement	Pre-placement	Review.	Correct placement methods and plant proposed.	Written approval by the CQA Engineer	Request revisions Record problem and solution on CQA Form 1
Aggregate Placement	During placement	Supervise, inspect and record.	Plant and methods employed compliant with agreed method statement No damage to underlying liner system and leachate control items.	No action unless non-compliant	Instruct remedial work Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

LEACHATE DRAINAGE AGGREGATE 2

MATERIAL/ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Aggregate Compliance	During placement	Visual inspection	Visual assessment of aggregate for compliance No unusual stone sharps / objects that may damage underlying liner system	No action unless non-compliant	Instruct remedial work Record problem and solution on CQA Forms 1 & 3.
Layer Thickness – Initial Check	Post placement on 25m square grid pattern	Trial holes	≥500mm perpendicular thickness on base and sidewalls ≥1,000mm perpendicular thickness beneath target pads ≥500mm perpendicular thickness over the leachate pipework		
Thickness and Extent Survey	During and post installation	Supervise survey of the extent and thickness of placed aggregate.	Points taken at the frequencies detailed in the Specification. Extent of aggregate placed picked up Perpendicular thickness to be as detailed above.	Prepare CQA Drawing 17 by reference to CQA Drawings 16 Verbal approval	Instruct and supervise appropriate remedial works Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.

CQA PROGRAMME

LEACHATE DRAINAGE PIPEWORK

MATERIAL/ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Drainage pipe/leachate collection pipe	Pre-delivery	Assess suitability of pipe for intended use from Spec.	Correct product type. Meets Specification requirements. Suitable strength for intended use as proven by calculations for each diameter of pipe used.	Written approval for use	Instruct pipe of compliant specification
Delivery, Storage & handling	Pre-installation	Visual		Verbal. In accordance with manufacturers recommendations	Instruct remedial work. Record problem and solution on CQA Forms 1 and 3
Leachate pipework installation	During installation	Supervise, inspect and record.	i) Correct pipe bedding conditions ii) Correct placement method. iii) Pipe in correct positions as shown on design plan iv) Pipe not damaged v) No damage to underlying liner system vi) Correct compaction of bedding vii) Correct joints used and electrofusion or butt welded viii) Caps fitted to upgrade ends ix) Information for pipe welding provided by installer as set out in specification	Verbal Approvals	Instruct remedial work/new installation Record problem and solution on CQA Forms 1 & 3.
Leachate pipework installation survey	During installation	Supervise survey to pick up the location and top of all pipework including end points	Points taken at 10m chainage points, all pipework including all pipe connections & pipe end points.	As built layout reflects agreed design layout. Prepare CQA Drawing 16 & 17.	Instruct resurvey as necessary Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

LEACHATE MONITORING POINTS, LEACHATE CHAMBER

MATERIAL/ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDIATION
Level & Location of Basal Concrete Slab	Pre-installation	Supervise electronic survey and visual inspection	Compliant levels, locations and dimensions ECL at correct thickness (500mm) beneath the base	Prepare CQA Drawings 16 & 17 Verbal approval	Instruct remedial work Record problem and solution on CQA Forms 1 & 3.
Materials Supplied	Pre-installation	Assess suitability of proposed materials for intended use from Spec. using test data and information provided by Contractor.	All materials meet Specification requirements for all relevant parameters. Contractor to provide appropriate information for assessment.	Written approval for use	Contractor to find compliant materials. Contractor to provide appropriate information for assessment. Record problem and solution on CQA Forms 1 & 3.
Materials Installation	During installation	Supervise, inspect and record.	Materials correctly installed with consideration given to: No damaged materials installed or damaged by installation of subsequent materials Correct grade & thickness of concrete used with correct reinforcement concrete placed with vibratory poker and allowed to cure. Products proposed are installed correctly. Structure complies with Specification & is vertical.	Verbal Approvals	Instruct remedial work/new installation Record problem and solution on CQA Forms 1 & 3.
CQA Records	During installation	n/a	CQA Engineer to record progress and compliance on CQA Form 1 and make a photographic record of installation works.	N/A	Record problem and solution on CQA Forms 1 & 3.
As built survey	During and post installation	Supervise electronic survey and visual inspection.	As built locations and dimensions compliant with Specification.	Verbal approvals. Prepare CQA Drawings 16 & 17	Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

GEOCOMPOSITE DRAIN 1

MATERIAL/ITEM	INTERVAL	CQA REQUIREMENTS	ACCEPTANCE CRITERIA	COMPLIANCE	REMEDIATION
CQA Programme and Method Statement	Pre-commencement	Review CQA programme and installation method statement provided by contractor	Comprehensive, suitable, adequate, & compliance with Contract requirements	Written approval File documents	Liaison with contractor/regulator for further information and/or rectification
Suitability of product	Pre-delivery	Review proposed product specification against specification	Compliance with Specification – Table 10.1	Written approval File documents	Liaise with contractor. Reject product as necessary. Review new product.
Roll Delivery	Per batch to site	Review/record roll details and factory QC test results / data sheets	Product delivered correct. Details match rolls; all rolls covered by QC information. Manufacturers QC sheets conform with manufacturers specifications.	Approve rolls/batch for use on site. Complete CQA Form 22 and file records.	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3. Prevent use of roll until compliant data provided.
Roll Delivery	Per batch to site	Supervise unloading.	No damage to rolls. Record method of unloading.	Approve rolls/batch for use on site. Complete CQA Form 22 and file records	Liaise with contractor. Reject rolls as necessary. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Storage of rolls	Per batch	Visual inspection	Compliance of location and method of storage with manufacturers recommendations and specification	N/A	Instruct remediation. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3

CQA PROGRAMME

GEOCOMPOSITE DRAIN 2

MATERIAL/ITEM	INTERVAL	TEST	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDICATION
Roll deployment	1 per panel	Visual inspection	No defects/damage. Compliance with panel layout requirements. Temporary surcharge used as necessary	In accordance with specification	Instruct repair and/or rejection/remediation of sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3
Installation – general	Per sheet margin	Visually inspect sheet margin	Subgrade acceptable. Aligned correctly. No wrinkles or crimps. Adjacent sheets butt joined. Compliant with installer's method statement and Specification.	Verbal approvals.	Instruct remedial work and/or reject seam / sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Repairs	As necessary	Visual inspection	In accordance with criteria in Specification.	Verbally approve repairs.	Instruct remedial work and/or reject seam / sheet. Record problem and solution on Daily Diary CQA Form 1 and CQA Form 3.
Survey	Following completion of installation and or prior to edge covering by soils, if applicable	Supervise electronic survey and visual inspection.	As built location of GDL edges compliant with Specification.	Verbal approvals. Prepare CQA Drawings 17	Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

Electrical Resistivity Leak Testing Survey (ERLTS)

MATERIAL/ITEM	INTERVAL	TESTS	ACCEPTANCE CRITERIA	ACCEPTANCE PROCEDURE	REMEDIATION
Proposed Specialist Contractor	Pre-attendance on site	Assess suitability of proposed sub-contractor using information and method statement provided by Contractor.	Qualified, experienced sub-contractor. Adequate and suitable method statement	Written approvals	Compliant sub-contractor to be resourced and or method statement to be revised. Record problem and solution on CQA Forms 1 & 3.
Leak Testing	During attendance on site	CQA Engineer to introduce anomaly for investigation by sub-contractor or sub-contractor to carry out appropriate self test, as agreed with CQA Engineer.	Anomaly detected and investigated. Self testing successful / compliant with limits set by sub-contractor in method statement.	Results to be reported by sub-contractor in leak test certification report.	Record problem and solution on CQA Forms 1 & 3.
Leak Testing	During attendance on site	Grid set out accurately Perimeter of test area cleared properly Physical conditions on site enable successful leak test All anomalies investigated.	Visual inspection	Results to be reported by sub-contractor in leak test report.	Record problem and solution on CQA Forms 1 & 3.
Repair work	During attendance on site	Proper repair procedures to be applied	All required repairs carried out by FML installation contractor in accordance with Specification and CQA Plan. Repair retested for leaks	Refer to CQA Plan and relevant tables above All repairs and retests to be reported by sub-contractor in leak test report	Record problem and solution on CQA Forms 1 & 3.

CQA PROGRAMME

OTHER MATTERS

MATERIAL/ITEM	INTERVAL	ACTION
Liaison with EA	As Required	Inform, discuss and agree. Fax weekly report. Immediate notification of Non compliance and any alterations to Specification or Construction Quality Assurance Plan.
Certifying Reports	As required - Post-operation	Comprehensive record of all relevant matters/details inc. “as built” drawings and photo record and reference index. (See Appendix A CQA Forms and Drawings – Relevance for application of CQA Forms)
Progress Meetings	Fortnightly (2 week)	Meeting of relevant Contractors, CQA Engineer and Client personnel to discuss progress.
Head Office back-up	As required	Availability of experienced staff to provide advice as required on issues arising etc.

CQA Engineer Site Handover Guidance & Record Sheet			
TCL = TerraConsult Ltd			
Issue - March 2009			
Item	Responsibilities of the Outgoing Engineer	Responsibilities of the Incoming Engineer	Done ?
Safety Specific safety risks for TCL staff	Describe all site specific risks to TCL staff	Make notes for reference	
Safety induction	Arrange for Main Contractor foreman to provide induction	Attend induction and make notes for reference	
TCL contractual responsibilities	Services plan shown to incoming engineer; responsibilities to be described to incoming engineer from risk assessments and method statements	Make notes for reference	
TCL CDM safety responsibilities	CDM layout plan shown to incoming engineer; areas to be described and explained; any safety issues relating to the project are to be described	Make notes for reference	
General Matters Key project staff	Prepare list of key project staff - client engineer/s, client operations staff, main contractor staff, sub-contractor staff, TCL staff; to include contact details	Keep list for future reference	
Working hours	Inform incoming engineer	Make notes for reference	
Site access & lock-up arrangements	Inform incoming engineer of the arrangements and handover all relevant keys and codes, client contact names and telephone numbers	Make notes for reference	

CQA Engineer Site Handover Guidance & Record Sheet			
TCL = TerraConsult Ltd			
Issue - March 2009			
Item	Responsibilities of the Outgoing Engineer	Responsibilities of the Incoming Engineer	Done ?
Works summary	Provide a summary of the ongoing works to the incoming engineer to include projected overall programme and a summary of the design and objectives of the project	Make notes for reference	
Progress meetings	Provide the date for the next progress meeting, who attends and provide copy of the minutes of the last meeting to the incoming engineer; talk through any key issues in the minutes	Keep minutes for future reference	
Specification Specification documents	Present copy of specification with drawings Inform current stage of the works Inform of the outstanding issues relating to the specification such as any proposed amendments, awaited EA decisions and how these will affect the TCL work and contractor's work Describe programme of the works including CQA work related to each stage of construction; use contractor's programme for reference	Maintain on site in good condition Make notes and learn detailed specification of the current works and of the next stage of works Make notes for reference Keep copy of programme for reference	

CQA Engineer Site Handover Guidance & Record Sheet TCL = TerraConsult Ltd Issue - March 2009			
Item	Responsibilities of the Outgoing Engineer	Responsibilities of the Incoming Engineer	Done ?
Detailed Specification	Talk incoming engineer through the spec requirements for the current layer / stage of work to include layer thickness and test result requirements Describe any problems with achieving specification with reasons and agreed actions to be undertaken, as appropriate	Make notes for when undertaking CQA testing Make notes for when undertaking CQA testing	
Site Walkover	Show the incoming engineer around the site and works; focus on any problem issues linking back to discussions in the site office as detailed above. Visit all stockpiles of mineral and geosynthetic materials	Make notes for reference	
CQA Work			
Transportation	Explain arrangements for transporting himself and samples around the site		
CQA Plan	Talk through it with particular emphasis on current and the next items of work and testing	Maintain on site in good condition	
Compliance testing	Explain status of compliance testing - what is required; what is currently outstanding to meet minimum test frequencies; current panel no`s, test and sample references	Make notes for reference	
Sample collection and delivery to labs	Explain arrangements for sample collection and lab schedule preparation,	Make notes for reference	

CQA Engineer Site Handover Guidance & Record Sheet

TCL = TerraConsult Ltd

Issue - March 2009

Item	Responsibilities of the Outgoing Engineer	Responsibilities of the Incoming Engineer	Done ?
Records	Outgoing engineer to bring up to date all daily records, CQA test record	Understand where all records are stored and any	
Equipment handover	sheets and graphs including test location plans and panel layout plans Prepare listing of outstanding data from the contractor eg FML data sheets Outgoing engineer to handover all notebooks, computer and or full records, memory sticks, keys to CQA store and office	outstanding work to get them up to date Chase up contractor to provide outstanding information	

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CQA Engineer - Protocol for Unexpected Absence - Guidance & Record Sheet

TCL = TerraConsult

Ltd

Issue 1 - March 2009

Item	Responsibilities of the Engineer	Responsibilities of the TCL Office	Done?
Continuation of the Works	The Contractor shall have the following three main options open to him in the event of an unexpected CQA engineer absence, subject to the instruction of the Engineer to the Works and to the agreed conditions of contract: 1 Stand awaiting instruction from the Engineer to the Works. 2 Undertake works not requiring CQA supervision. 3 Undertake works requiring CQA supervision but subject to subsequent inspection and testing prior to being covered. It is to be noted that the CQA Engineer is to advise the Contractor and or Engineer to the Works as to the most appropriate option for any one planned activity.	TCL office is to liaise between the Contractor, Engineer to the Works and the replacement CQA engineer to enable as much as possible the continuation of the Works without delays being incurred or with the minimum of delay.	
Replacement Engineer Actions to be taken by TCL office	The replacement engineer is to phone the original engineer for a detailed briefing on the status of the construction works and the status of the CQA testing and records. Both engineer's are to follow as much as is possible the standard requirements for site handover, detailed separately.	Jim Waterworth, Matt Gill or Iain Jones are to find and provide a briefing to a replacement CQA engineer. The replacement CQA engineer is to travel to site as soon as is possible.	
Safety	The replacement engineer is to arrange for Contractor foreman to provide induction on arrival at the site as well as sign in and report to the foreman. The replacement engineer is to follow site safety regulations at all times.	The TCL office is to ensure that the replacement CQA engineer has been inducted by the client for work on their landfill sites; if not arrangements are to be made for the CQA engineer's induction.	

CQA Method Statement – Proforma Portfolio

CQA FORMS

List of Proforma Forms to be included:-

GENERAL

1. Daily site record
2. Weekly site record
3. Non compliance record

TEMPORARY GROUNDWATER MANAGEMENT SYSTEM

4. Trial pit record

CLAY SUBGRADE

5. Clay liner subgrade approval record

CLAY LINER

6. NDG test results data sheet and moisture density graph
7. Field core test results data sheet and moisture density graph
8. Hand vane shear strength test record

GEOSYNTHETIC CLAY LINER

9. GCL roll delivery record
10. GCL subgrade acceptance record
11. GCL deployment record
12. Accessory bentonite seam record
13. GCL defects / repair record

GEOMEMBRANE LINER (FML)

14. FML roll delivery record
15. FML subgrade acceptance record
16. FML deployment record
17. Trial seam record
18. Fusion seam weld record
19. Extrusion seam weld record
20. Non destructive seam testing record
21. FML defects / repair record

PROTECTIVE GEOTEXTILE

22. Geotextile roll delivery record
23. Geotextile deployment record
24. Geotextile repair record

25. Not Required

STRUCTURES

26. Construction check list

LEACHATE DRAINAGE LAYER

- 27. Drainage Layer Thickness Trial Pit Record
- 28. Filter Geotextile roll delivery record

CQA DRAWINGS

List of CQA Drawings to be included:-

GENERAL

- 1. Drawing 1 – Survey of original ground level
- 2. Drawing 2 – Not Required

CLAY SUBGRADE

- 3. Drawing 3 – Survey of clay liner formation level
- 4. Drawing 4 – Not Required
- 5. Drawing 5 – Not Required

CLAY LINER

- 6. Drawing 6 – Survey of top of clay liner
- 7. Drawing 7 – Not Required
- 8. Drawing 8 – Not Required
- 9. Drawing 9 – Clay liner thickness
- 10. Drawing 10 – Positions of CQA testing and sampling of the clay liner

GEOSYNTHETIC CLAY LINER

- 11. Drawing 11 – GCL panel layout

GEOMEMBRANE LINER (FML)

- 12. Drawing 12 – FML panel layout

PROTECTIVE GEOTEXTILE

- 13. Drawing 13 – Protective geotextile panel layout
- 14. Drawing 14 – Not Required
- 15. Drawing 15 – Not Required

LEACHATE COLLECTION & EXTRACTION SYSTEM

- 16. Drawing 16 – Survey of top of leachate drainage layer and as constructed system layout
- 17. Drawing 17 – Survey of leachate drainage layer thickness and as constructed system layout including geocomposite drainage layer as-installed extent

CQA VALIDATION REPORT DRAWINGS

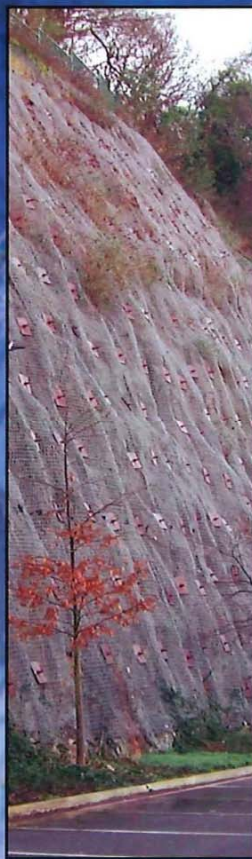
List of CQA Drawings to be included in the validation report:-

1. Drawing 3
2. Drawing 6
3. Drawing 9
4. Drawing 10
5. Drawing 11
6. Drawing 12
7. Drawing 13
8. Drawing 16
9. Drawing 17

As built drawings will be presented in the validation report to include the following items:
Title of project, contract, element of works; Drawing version number, with details of revision history;
Scale (Scale at size to be printed, eg 1:500 at A1); Details of the Survey Grid; Locations of control
stations/levels, benchmarks, etc. (permanent and temporary); North arrow; Grid intersections;
Distinguish between surveys done on different times and dates

APPENDIX D

STABILITY RISK ASSESSMENT



March 2015
Report No 2185/R/001-01-SRA

WITHYHEDGE LANDFILL SITE VALLEY CELLS STABILITY RISK ASSESSMENT

Carried out for:



PottersWasteManagement



WITHYHEDGE LANDFILL SITE VALLEY CELLS

STABILITY RISK ASSESSMENT

Date: 11th March 2015

Carried Out For:



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DOCUMENT INFORMATION AND CONTROL SHEET

Document Status and Approval Schedule

Report No.	Title
2185/R/001-01-SRA	Withyhedge Landfill Site Valley Cells Stability Risk Assessment

Issue History

Issue	Status	Date	Prepared and Approved By	Signature	Date
1	Final	11.03.2015	Prepared and Approved By A. Binns BSc CEng FICE 		11.03.2015
			Checked By: P Kavanagh BEng CEng MICE		11.03.2015

DISCLAIMER

TerraConsult Ltd completed this consultancy contract on the basis of a defined programme and scope of works and terms and conditions agreed with the client. This report was compiled with all reasonable skill, and care, bearing in mind the project objectives, the agreed scope of works, the prevailing site conditions, the budget, the degree of manpower and resources allocated to the project as agreed.

TerraConsult Ltd cannot accept responsibility to any parties whatsoever, following the issue of this report, for any matters arising that may be considered out with the agreed scope of works.

This report is issued solely to the client and TerraConsult cannot accept any responsibility to any third parties to whom this report may be circulated, in part or in full, and any such parties rely on the contents at their own risk.



WITHYHEDGE LANDFILL SITE VALLEY CELLS

STABILITY RISK ASSESSMENT

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2185/2/005	Cell Lining System
2185/2/006	Leachate Extraction Chambers
2185/2/007	Cell Edge Details
2185/2/004	Waste Placement phasing

Appendix A Global Stability - FLAC/Slope outputs

Appendix B Stability of Leachate Monitoring Point

WITHYHEDGE LANDFILL SITE VALLEY CELLS

STABILITY RISK ASSESSMENT

INTRODUCTION

Report Context

1. TerraConsult Ltd (TCL) was instructed by Potters Waste Management (the Client), to undertake a Stability Risk Assessment (SRA) for the infilling of the Valley Cells at Withyhedge Landfill Site, near Haverfordwest, Pembrokeshire, Wales.
2. It is proposed to infill the current void that exists between Phase 1 and Phase 2 at the site. The position of the valley cells relative to the cells in Phases 1 and 2 is shown on Drawing No 2185/2/001. Waste will be deposited in the existing valley feature effectively joining Phase 1 and Phase 2. The waste to be deposited will be of similar nature to that currently being deposited in Phase 2.
3. The SRA addresses, with regard to the geological setting of the site and water levels, the following:
 - a. The global stability of the unconfined waste mass with basal and sidewall subgrades.
 - b. The stability of the leachate monitoring chimneys.

The veneer stability of the capping system has been dealt with previously and is not repeated in this report.

Site Location and General Description

4. Withyhedge Landfill Site is located approximately 5.5 km north of Haverfordwest, Pembrokeshire at National Grid Reference SM 970 217.
5. The landfill is located within the shallow valley of Rudbaxton Water, a tributary of the Western Cleddau, within a predominantly rural area and is bounded to the south, east and west by agricultural land with occasional small wooded areas, hedgerow and marsh land.
6. To the north the landfill is bounded by Rudbaxton Water, which is designated a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC).
7. The Paddington to Fishguard mainline is situated beyond Rudbaxton Water, approximately 70 m to the north of the installation boundary. The nearest main settlement, the village of Spittal, is located 1 km to the north east whilst the small settlement of Rudbaxton is situated approximately 650 m to the south west. Haverfordwest Aerodrome is located approximately 1.45 km to the south west of the site adjacent to the A40 Haverfordwest to Fishguard Road.

8. The site is accessed via the A40, a rural lane and a long private access road leading from the site entrance near the settlement of Rudbaxton.
9. The site has been operational since October 1985 prior to which the site existed as poorly drained agricultural land.
10. Waste has been deposited in Cells 1 to 15 subsequently referred to as Phase 1. In June 2005 a second PPC permit application was made for the remaining unfilled parts of the site known as Phase 2. This permit was granted in March 2006. Phase 2 is currently active and separated from the existing site (Phase 1) by the valley feature which is the focus of this SRA.
11. In general, ground levels around the perimeter of Phase 1 fall from around 58 m OD on the southern boundary to around 36 m OD at Rudbaxton Water to the north.
12. Phase 1 was effectively filled in a series of cells, the older areas did not benefit from the installation of an engineered basal lining system. However the cells constructed later have been engineered. Cells 11, 13 and 14 have an engineered clay lining system and Cell 15 has a composite clay and High Density Polyethylene (HDPE) liner.
13. Filling is currently taking place in Phase 2 with Non Hazardous Waste (including inert waste that may be used for cover and restoration).
14. The infilling of the valley feature will allow progression towards achieving the current permitted final restoration landform.

CONCEPTUAL STABILITY SITE MODEL

Site Dimensions and Topography

15. The valley base is approximately 370m long north-south and varying between 5m wide in the north to 15m wide in the south, as shown on Drawing 2185/2/005.
16. In general, ground levels around the perimeter of Phase 1 fall from around 58 m OD on the southern boundary to around 36 m OD at Rudbaxton Water to the north.

Landfill design

Summary of Basal Lining

17. The basal containment liner comprises a composite system with the following components:
 - a. A geological barrier of re-worked clay overburden, with a maximum hydraulic conductivity of 1×10^{-8} m/s and a thickness of 500mm;
 - b. A geosynthetic clay liner (GCL) with a maximum hydraulic conductivity of 1.0×10^{-11} m/s.
 - c. An artificial sealing liner comprised of a 2mm textured high density polyethylene (HDPE) flexible membrane liner (FML);
 - d. An overlying protective geotextile of non-woven, needle-punched manufacture of a 1200g/m^2 grade or similar (subject to cylinder testing results) to provide sufficient protection from the anticipated waste loading;
 - e. A 300mm thick stone leachate drainage blanket.

f. A filter geotextile.

The individual components of the basal lining system are discussed in greater detail below.

Geological Barrier

In-Situ Geological Barrier

18. A minimum 1m thick unsaturated zone will be maintained under the engineered lining system.
19. Currently the southern section of the valley feature has a site access road located at the base of the valley; the road construction is approximately 1m thick and terminates adjacent to Cell 15. In order to create appropriate formation levels the small sections of the road that provide ramped access into Phase 2 will require re-grading. If suitable this material will be re-used in the formation layer under the cell base. Additional material may also be required to create appropriate falls.
20. The northern section of the valley (Cells N1-N3) will be constructed to a 1:50 fall towards the north. The southern section of the valley (Cell S1) will fall towards the adjacent Cell 1/2 south. The existing bund along the eastern flank of Cell 1/2 South will be reduced in height to facilitate the linking of the areas and the material excavated will be used to raise levels of the southern cell to create a fall of 1:50 from west to east.
21. The 1m unsaturated zone will therefore consist of a variety of materials. In the northern half of the cell the unsaturated zone will predominately consist of the existing in-situ ground. The unsaturated zone under the southern half of the cell will consist of a combination of the existing site road and in-situ ground.
22. When material is placed in the valley to form appropriate levels it will be selected and placed in accordance with the Highways Specification to ensure suitable stability.

Artificially Established Geological Barrier

23. This will be constructed from re-worked clay derived from on-site sources. Appropriate testing has demonstrated the permeability of this material. The suitability of this material for its intended purpose has been demonstrated by its use for landfill lining purposes in Phase 2. This will be supplemented by the use of a Geosynthetic Clay Liner (GCL).

Artificial Sealing Liner

24. The upper component of the composite lining system is a flexible membrane liner (FML) of 2mm thick HDPE sheet. This will be laid in intimate contact with the GCL. The FML will be of a design that incorporates a roughened texture on both its underside and top side to increase friction along the interfaces between the FML and neighbouring materials.

Sidewall Lining System

25. Reference is made to Drawing 2185/2/007 – Cell Edge Details. The sidewall lining system will be formed by an extension of the basal composite lining system to the crest of the adjacent bunds. No lining system will be placed against adjacent waste with the exception of the preferential leachate drainage system installed on the flank of Cell 13. Full details of this leachate collection system are given below.

Geology

26. The site geology was assessed using the Regional Geology map given on Drawing No. ESID9 (Golder Associates, 2005) as well as borehole and trial pit logs (Golder Associates, 2005).
27. The site has been developed on Quaternary fluvio-glacial deposits, which are underlain by solid geology comprising Mydrim and Hendre Shales. The geological succession is summarised in Table 1.

Table 1 – EC7 Summary of Geology beneath Withyhedge Landfill Site

Age	Strata	Description	Thickness (m)
Quaternary	Fluvio-glacial deposits	Clay with silt, sand and gravel	0.0 – 5.4
Ordovician	Mydrim and Hendre Shales	Fissile and heavily cleaved dark blue grey slightly carbonaceous shale	152 – 183

Superficial Deposits

28. The fluvio-glacial deposits are typically described as orange to grey, soft to firm silty clay with occasional sand lenses and gravel and cobble size fragments.

Bedrock Geology

29. The Mydrim and Hendre Shales encountered on site are typically described as moderately weak to strong dark grey, grey and black, fissile, occasionally carbonaceous shales. The shales typically exhibit a weathered profile with firm to stiff brown grey, grey, orange brown clay with much gravel of shale of between 0.3 and 2.5m thickness overlying more competent strata.
30. The geological map indicates that the bedrock dips to the south-east at angles of 20-30°.

Groundwater

31. The Mydrim Shale is described as a non-Aquifer therefore it is a formation which is generally regarded as containing insignificant quantities of groundwater. The sand and gravel identified is classified as a minor aquifer.
32. Groundwater is found to be at relatively shallow depths beneath much of the site. It was considered that the water strikes in the fluvio-glacial deposits reflect bands or lenses of material with a greater sand and gravel content, while water strikes in the mudstone unit are associated with fractures and fissures in the mudstone (Golder Associates 2005).

33. In the site investigation undertaken by AIG in 2003, the groundwater was again found to be close to ground level, between 0.6 and 2.7m bgl (39.66 and 40.30m OD respectively) (Golder Associates 2005).

Material Properties FLAC/Slope Analysis

34. A summary of the characteristic densities and shear strength parameters for the material types considered in the slope stability analysis (using FLAC/Slope computer software) is presented in Table 2. These parameters have been based on the previous work carried out by Golder Associates and AIG Consultants together with the experience of TerraConsult Limited (TCL) with similar materials in the area and are considered by TCL to be appropriate.
35. Both short term (ie undrained) and long term (i.e. effective) strength parameters have been considered in the analysis.
36. The parameters listed in Table 2 represent the characteristic values selected for the FLAC/Slope stability assessment. In accordance with Eurocode 7 partial factors have then been applied to obtain the design values for Combination 2 used in the analysis. The design material parameters for Combination 2 are also presented in Table 2.

Note: Only Combination 2 is considered in this assessment of slope stability because any imposed loadings are negligible compared to the soil masses. The assessment of the stability of the cell furniture, however, considers both short term and long term stability in which the material parameters are for Combination 1 ie are the characteristic shear strengths given in Table 2.

Table 2 – EC7 Characteristic and Design Combination 2 material parameters for use in FLAC analysis and foundation design

Material	EC7 Characteristic material parameters			EC7 Design Combination 2 material parameters			Unit weight (kN/m ³)		Source
	Undrained	Effective stress		Undrained	Effective stress				
	c _{u k} kN/m ²	c' _k kN/m ²	ϕ' _k deg	c _{u des} kN/m ²	c' _{des} kN/m ²	ϕ' _{des} deg	Moist γ _d kN/m ³	Sat' γ _{sat} kN/m ³	
Fluvio-glacial Deposits (clay)	50	2	23	35.7	1.6	18.8	20	21	Golder/AIG/SI
Clay Liner	50	3	23	35.7	2.4	18.8	20	22	Golder/AIG/SI and minimum c _u requirement for CQA

Material	EC7 Characteristic material parameters			EC7 Design Combination 2 material parameters			Unit weight (kN/m ³)		Source
	Undrained	Effective stress		Undrained	Effective stress				
	c _{u k} kN/m ²	c' _k kN/m ²	ϕ' _k deg	c _{u des} kN/m ²	c' _{des} kN/m ²	ϕ' _{des} deg	Moist γ _d kN/m ³	Sat' γ _{sat} kN/m ³	
Drainage Layer	0	0	30	0	0	24.8	18	18	Experience
Waste MSW		5	25		4	20.8	12	13	EA Report TR1
HDPE (rough) v GCL	0		30	0	0	24.8	10	10	Naue communication and Geospec Lab test ¹

Surcharge Loads

37. Surcharge loadings have not been considered in the FLAC/Slope analyses of global stability because they are negligible compared to the soil masses.

Justification for Modelling Approach and Software

38. Stability analyses were undertaken by considering the worst credible conditions likely to be encountered at the site.
39. The analysis of global stability was undertaken using the computer programme *FLAC/Slope* (version 7), which utilises the finite difference method of analysis. *FLAC/Slope* offers many advantages over traditional limit equilibrium based programmes.
- Limit equilibrium codes use an approximate scheme (typically based on the method of slices) in which a number of assumptions are made (eg the location and angle of the interslice forces). Several assumed failure surfaces are tested (often many hundreds), and the one giving the lowest factor of safety is chosen. Equilibrium is only satisfied on an idealised set of surfaces.
 - In contrast, *FLAC/Slope* provides a full solution of the coupled stress/displacement, equilibrium and constitutive equations. Given a set of properties, the system is determined to be stable or unstable. By automatically performing a series of simulations while changing the

strength properties (strength reduction technique), the factor of safety (= ODF in these analyses) can be found to correspond to the point of stability and the critical failure (slip) surface can be located. Hence:

1. Any failure mode develops naturally; there is no need to specify a range of trial surfaces in advance.
2. No artificial parameters (eg functions for interslice force angles) need to be given as input.
3. Multiple failure surfaces (or complex internal yielding) evolve naturally, if the conditions give rise to them.
4. The solution consists of mechanisms that are kinematically feasible whereas the limit equilibrium method considers only forces and not kinematics.

Analysis Approach

40. This stability risk assessment (SRA) has been carried out in accordance with the principles of Eurocode 7, which uses a partial factor method (on actions and strength), to determine the Over Design Factor (ODF).
41. Eurocode 7 is based on the principles of limit state design, whereby a design must ensure that no limit state is exceeded. With respect to the analyses presented in this report, the limit state of relevance is limit state GEO defined as “*failure or excessive deformation of the ground, in which the strength of soil or rock is significant in providing resistance*”, e.g. global stability of the landfill, bearing capacity of foundation soils.
42. Each limit state requires different partial factors to be used in the analysis. These are presented in the spreadsheet provided in Appendix B. It should be noted that the approach adopted in the UK for limit state GEO (Design Approach 1) requires two combinations of partial factors to be analysed as follows:

Combination 1 A1 + M1 + R1

Combination 2 A2 + M2 + R1

Where;

- A = Partial factors on actions (applied forces and moments);
- M = Partial factors on soil parameters; and
- R = Partial factors on resistances.

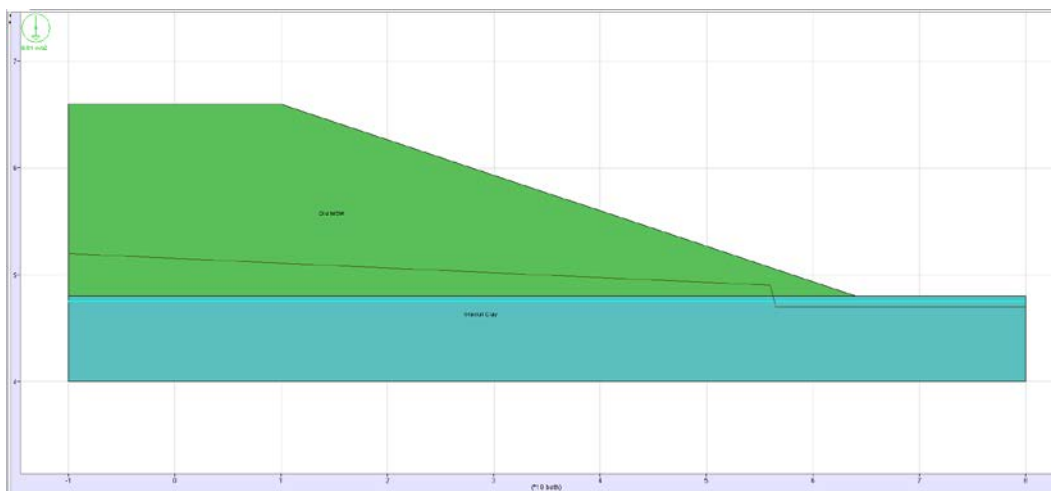
43. The values of various sets of partial factors that are applied to characteristic actions (A1 and A2), characteristic material strengths (M1 and M2) and resistances (R1) vary depending upon whether they are favourable or unfavourable to the stability of the structure. Note: Only Combination 2 is considered in this assessment because any imposed loadings are negligible compared to the soil masses.
44. When considering a limit state of rupture or excessive deformation EuroCode 7 requires that $E_d \leq R_d$ where:
 - E_d = design value of effect of actions (forces) and
 - R_d = design value of the resistance to actions

45. The ratio R_d / E_d can be defined as the Over Design Factor and stability is demonstrated when the $ODF \geq 1.00$. Hence, for each limit state considered, $ODF's \geq 1.00$ are required for the construction to be considered stable (i.e. safe).

ASSESSMENT OF THE GLOBAL STABILITY OF THE UNCONFINED WASTE MASS WITH BASAL AND SIDEWALL SUBGRADES

46. Reference is made to Drawings 2185/2/004 and 007. Two generalised cross sections across the valley cells have been analysed as shown below. The only mechanism possible for failure is that of the unconfined waste mass (ie with the valley only partially filled) slipping down into the valley and possibly causing disruption to the basal and/or sidewall liners. Section A represents the case when the new waste (placed over Phase 2) does not quite reach the Phase 1 side of the valley: Section B represents the case when the new waste has reached the Phase 1 side of the valley and intersects the geocomposite drain over the top of the old waste in Phase 1.

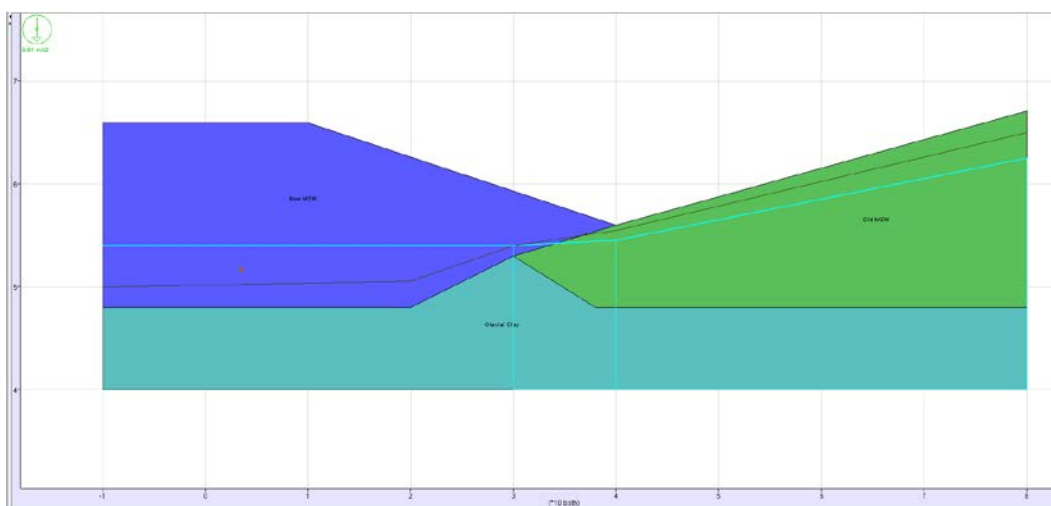
Phase 2 side of valley



Section A

Phase 2 side of valley

Phase 1 side of valley



Section B

Parameters

47. Effective strength parameters have been considered in the analysis.
48. The material parameters for Combination 2 are presented in Table 2. Note: Only Combination 2 is considered in this assessment because any imposed loadings that might occur are small compared to the soil masses.
49. The HDPE (rough) v GCL interface shear strength parameters have been assumed, conservatively, for the interface between the waste and the geosynthetic drain.

Water Levels

50. The water levels used in the analysis have assumed:
 - a. Groundwater at 1 m below the valley formation level – normal water levels
 - b. An increased head perched between 1m and 3m above the geosynthetic drain.

Analyses - Global Stability (GEO Limit State)

51. The outputs/results of the analyses are presented in Appendix A. In Appendix A the following should be considered when looking at the graphical outputs:
 - a. The X axis represents the distance along the section in $m \times 10^{-1}$.
 - b. The Y axis represents the reduced level of the various points in $m \times 10^{-2}$ at each distance along the section.
 - c. Unfortunately the units of strain contours cannot be plotted to a common scale as they are fixed by the software depending upon the range of strains produced. What the plot is used to show is where the critical failure (sliding) surface would be ie where the highest strains are concentrated.
52. The results of the analyses are summarised in Table 3.

Table 3 - Over Design Factors for waste mass, basal and sidewall subgrades stability

Notes:

The factor of safety quoted on the FLAC/Slope output sheets is the EC7 ODF in these analyses.

To obtain the approximate Factor of Safety in these analyses (effective stress with no surcharge loadings) the ODF is multiplied by 1.25.

Section/ Run	OVER DESIGN FACTOR	Factor of Safety (approx.)	Comment on analysis result
A - 01	1.51	1.89	Temporary slope. Normal water. Deep critical slip surface through waste on Phase 2 side of valley Very safe
A - 02	1.44	1.80	Temporary slope. Normal water. Deep critical slip surface through waste and onto liner on Phase 2 side of valley Very safe

Section/ Run	OVER DESIGN FACTOR	Factor of Safety (approx.)	Comment on analysis result
A - 09	1.25	1.56	Temporary slope. High water above basal liner Deep critical slip surface through waste and onto liner on Phase 2 side of valley Very safe
B - 03	1.81	2.26	Temporary slope. Normal water. Deep critical slip surface through waste on Phase 2 side of valley Very safe
B - 05	1.78	2.22	Temporary slope. Normal water. Deep critical slip surface through waste onto sidewall liner on Phase 2 side of valley Very safe
B - 08	1.57	1.96	Temporary slope. Water above geosynthetic drain. Shallow critical slip surface through waste along geosynthetic drain on Phase 1 side of valley Very safe

Assessment

53. The Over Design Factors (ODFs) are greater than 1.00 and, therefore, the design is considered to be stable.

ASSESSMENT OF THE STABILITY OF THE LEACHATE CHIMNEYS

54. The cross sections analysed for stability of the leachate monitoring chimneys are shown on Drawing No 2185/2/006 – Leachate Extraction Chambers.

Parameters

55. Both undrained and effective strength parameters have been considered in the analysis.
56. The characteristic material parameters are presented in Table 2

Water Levels

57. The water level was assumed at below the liner in line with investigation data.

Surcharge Loads

58. No Surcharge loading has been applied but downdrag on the chimney has been considered due to waste settlement relative to the chimney: this has been reduced because of the two layers of Visqueen wrapped round the outside of the chimney.

Analyses

59. The spreadsheets of the leachate monitoring chimneys analyses are presented in Appendix B:
- a. Based on undrained shear strength parameters an ODF of 3.99 was obtained for shear failure of the subgrade.
 - b. Based on undrained shear strength parameters an ODF of 3.7 was obtained for shear failure of the subgrade considering it to be a thin layer (liner) being squeezed from under the foundation.
 - c. Based on effective stress shear strength parameters an ODF of 3.10 was obtained for shear failure of the subgrade.
 - d. The strain in the liner with 21 m of waste in place was 0.08%, which is less than the 3% allowable strain quoted in the EA Landfill Guidance Standard, LFE4 "Earthworks in Landfill Engineering".

Leachate Monitoring Chimney Stability Assessment

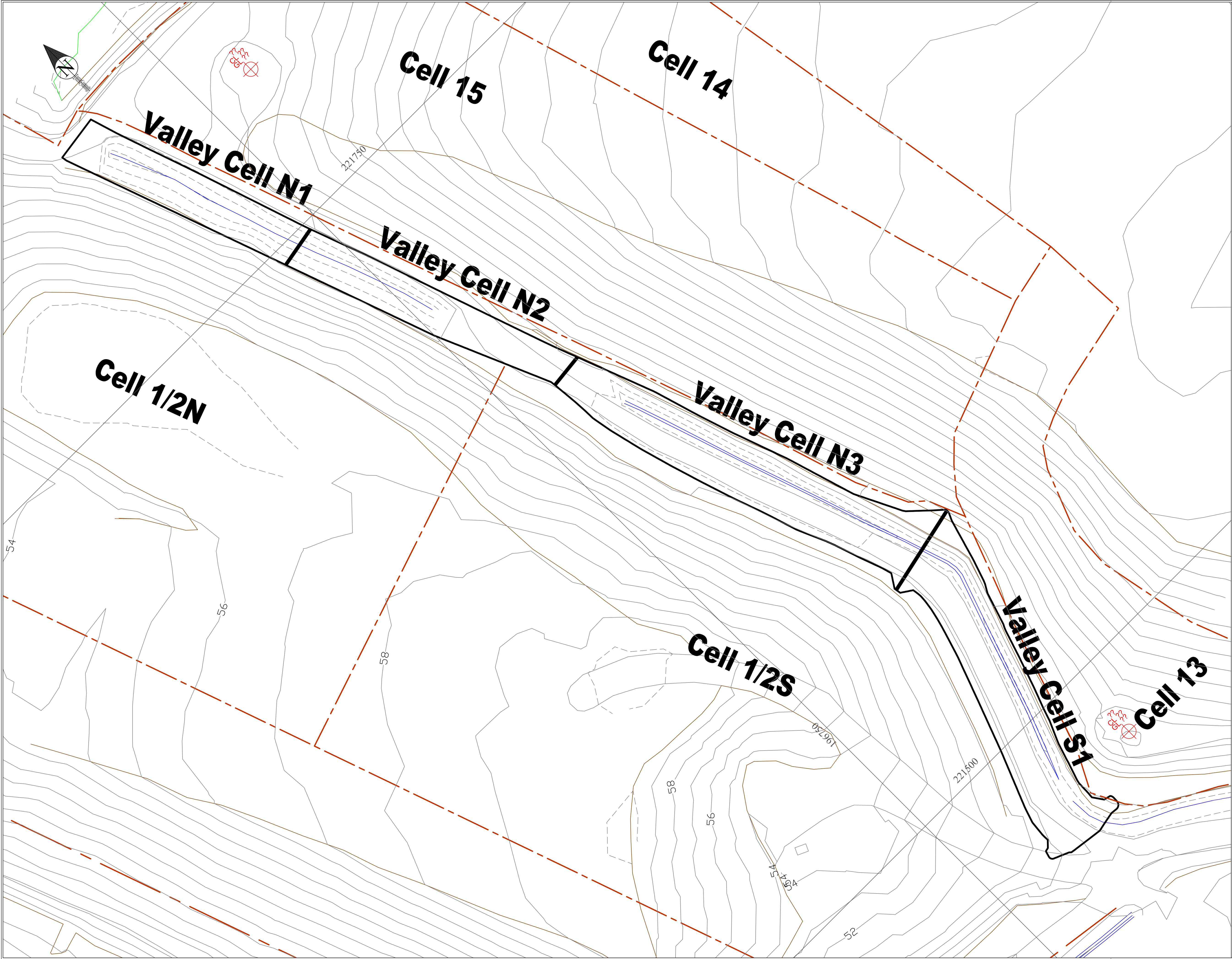
60. The Over Design Factors (ODFs) are greater than 1.00 with liner strain being minimal and, therefore, the leachate chimney foundation design is considered to be stable.

REFERENCES

1. EuroCode 7 – BS EN 1997 (published in 2 parts). Geotechnical Design. BSI.
2. EuroCode 7 – NA to BS EN 1997-1: 2004. UK National Annex to Eurocode 7: Geotechnical design – Part 1: General rules.
3. Environment Agency (2010), Earthworks in Landfill Engineering. Report LFE4, Environment Agency, Bristol.
4. Environment Agency (2003), Stability of Landfill Lining Systems: Report No. 1 Literature Review. R&D Technical report P1-385/TR1, Environment Agency, Bristol, pp 219.
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6. Jones and Dixon (1998), The stability of geosynthetic landfill lining systems, in '*Geotechnical engineering of landfills*' Ed N, Dixon, E J Murray and D R V Jones 99-130 Thomas Telford: London.
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9. Editors: Reeves GM, Sims I & Cripps JC (2006). Clay Materials Used in Construction, Geological Society (of London) Engineering Geology Special Publication No21
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11. Withyhedge Landfill Site, EP permit variation application. Technical standards, TerraConsult, October 2008.
12. Golder Associates, 2005. Withyhedge Landfill Phase 2, PPC Permit Application, June 2005. 04529421 Version A.0. Volume 2, Section C.

DRAWINGS
TERRACONSULT DRAWINGS

2185/2/001	Location plan
2185/2/002	Formation
2185/2/004	Waste Placement Phasing
2185/2/005	Cell Lining System
2185/2/006	Leachate Extraction Chambers
2185/2/007	Cell Edge Details



- Notes
- Topography Dec.14 (m OD)
 - Existing Cell outline
 - Outline of Valley Cell Lining

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PottersWasteManagement

Site

**Withyhedge Landfill
Valley Cells**

Title

Location Plan

Scale	1:500	@ A1
Drawing No.	2185/2/001	
Rev	Date	Description
File	21852001location.dwg	
Date	02/15	Engineer JW
Drawn	PT	Checked DRAFT



- Notes
- Topography Dec.14 (m OD)
 - Existing Cell outline
 - Cell Formation (1m contours) (m OD)

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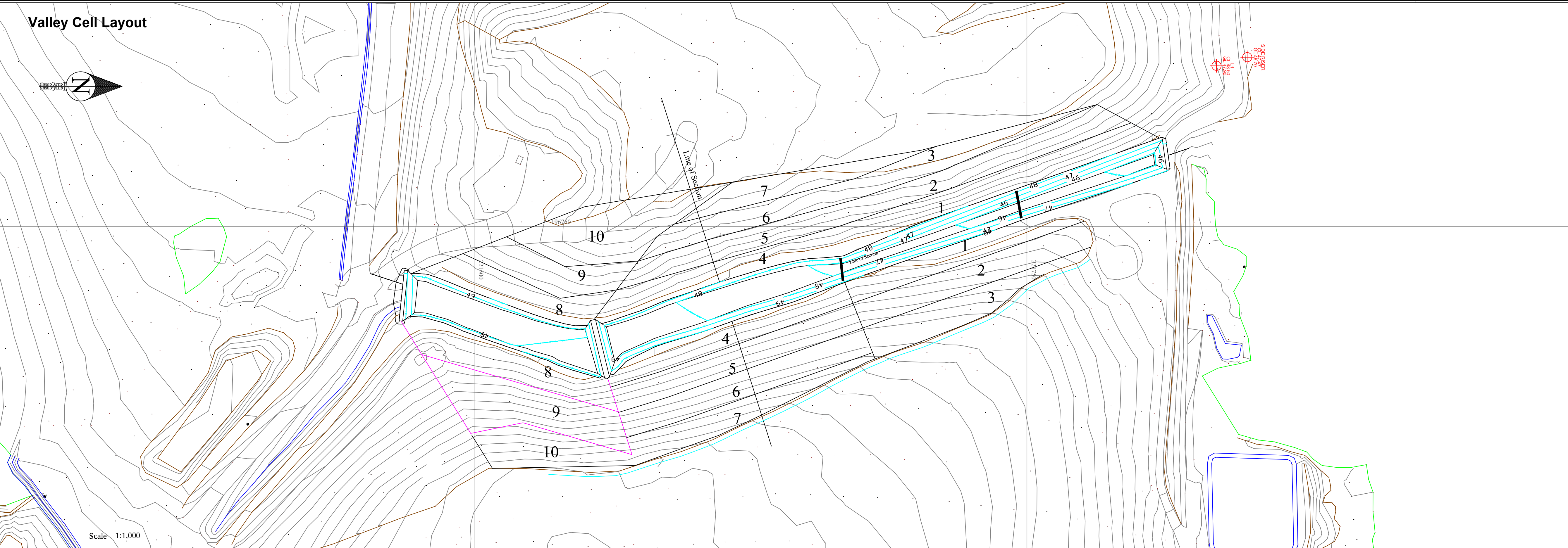
Site

**Withyhedge Landfill
Valley Cells**

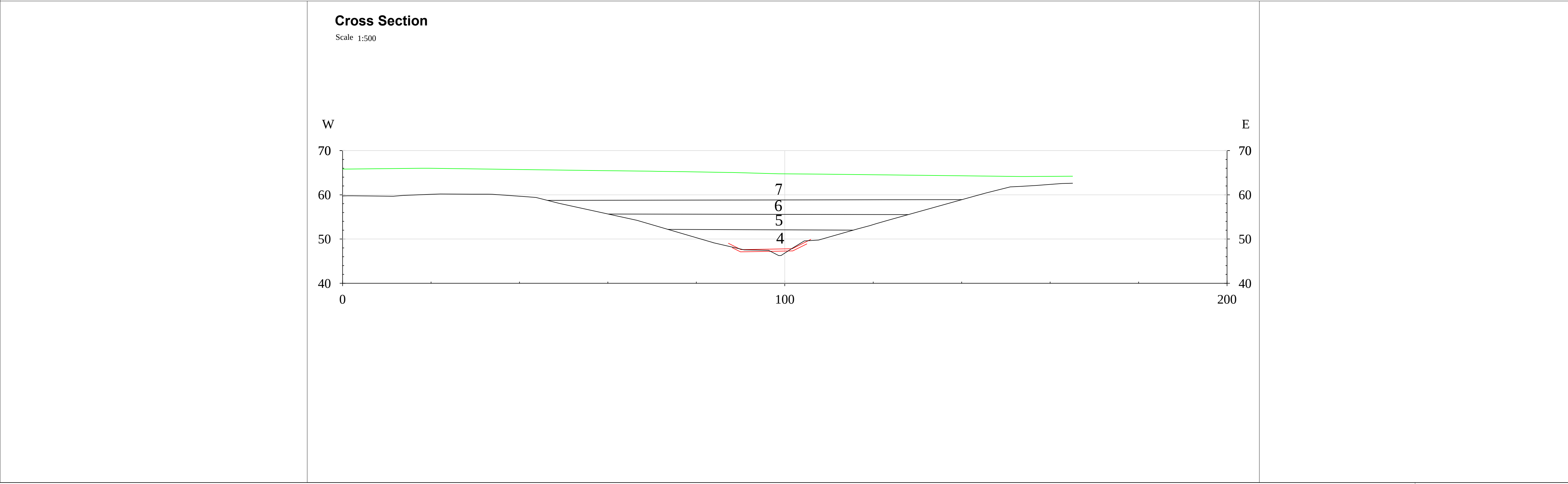
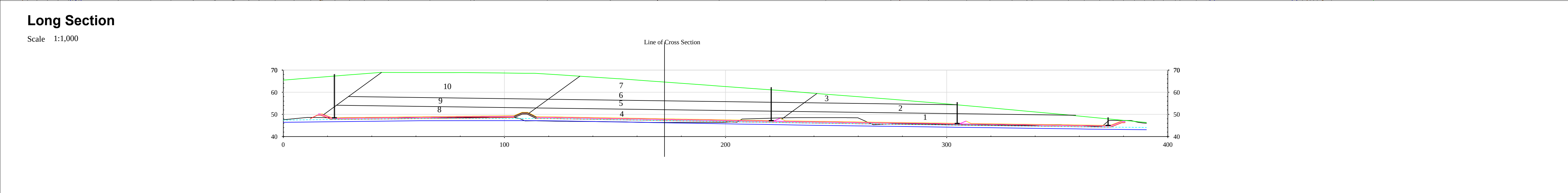
Title

Formation

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Drawing No.	2185/2/002	
Rev	Date	Description
File	21852002formation.dwg	
Date	02/15	Engineer JW
Drawn	PT	Checked DRAFT



- Notes
- Plan Legend
- Surface Water Cut-off ditch
 - Geocomposite Drainage Panel outline
 - Top of Engineered Clay Contours (1 metre intervals, m OD)
 - Waste placement phase
 - Waste placement panel outline
- Section Legend
- Restoration Surface
 - Waste Placement Phase
 - Lining System



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Client

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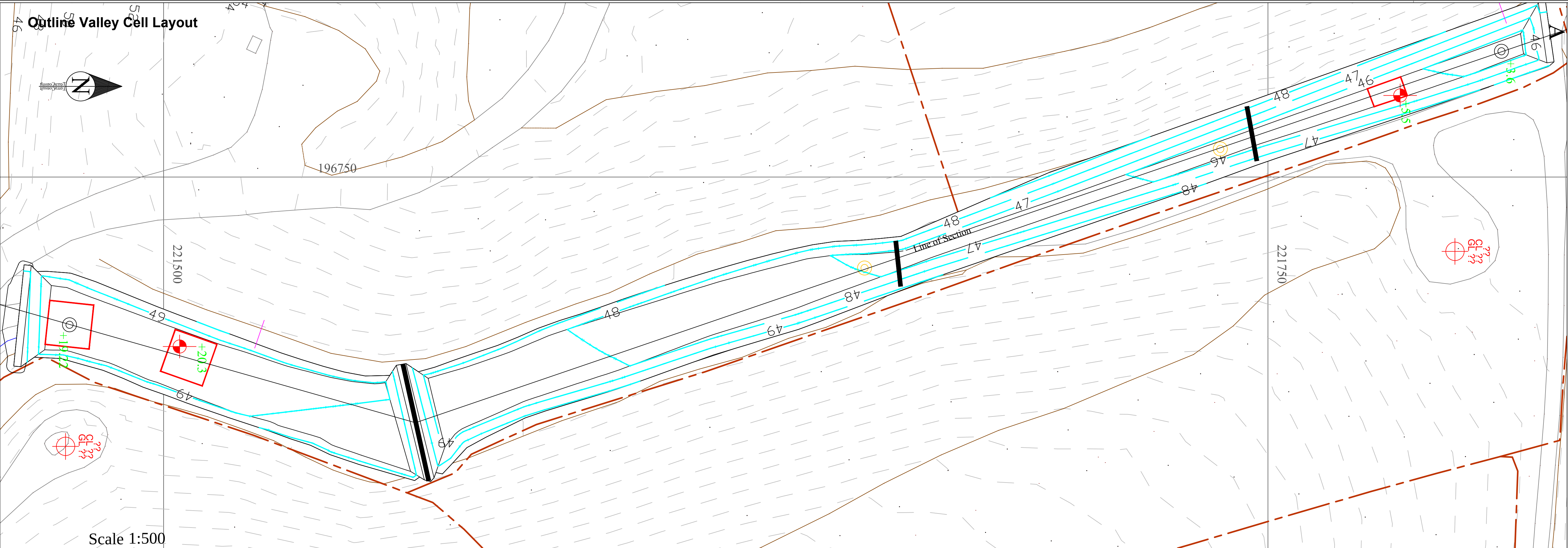
Site

**Withyhedge Landfill
Valley Cells**

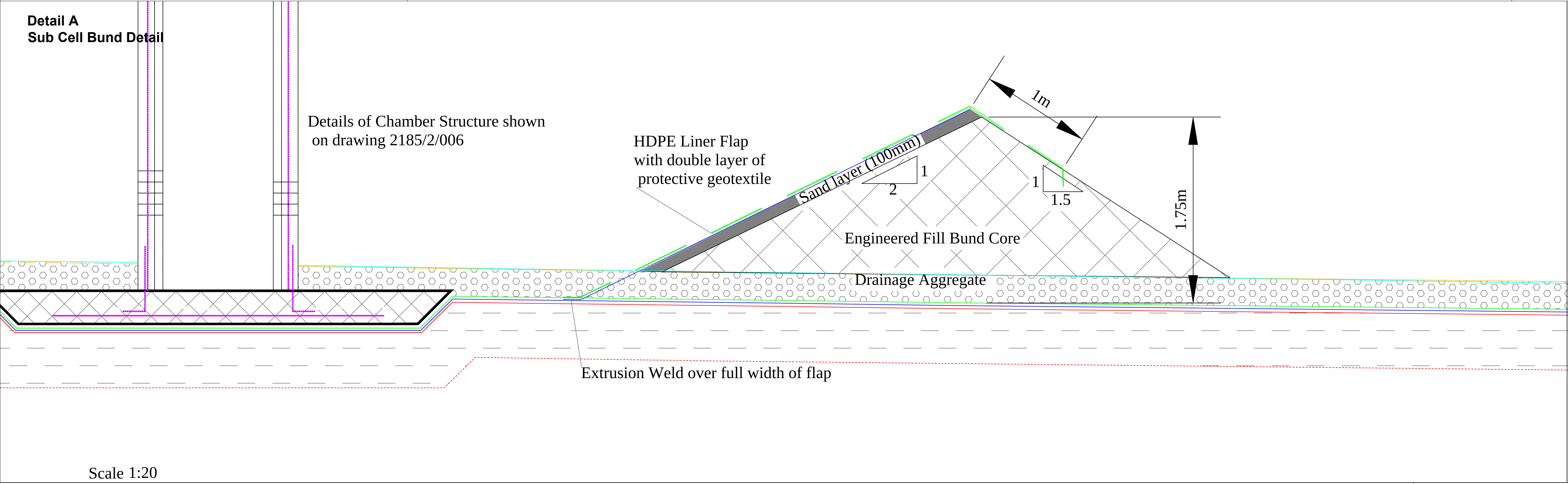
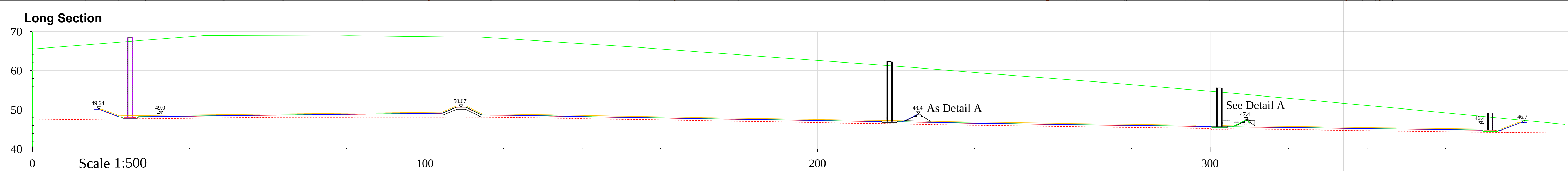
Title

Waste Placement Phasing

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Rev	Date	Description
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Date	02/15	Engineer JW
Drawn	PT	Checked DRAFT

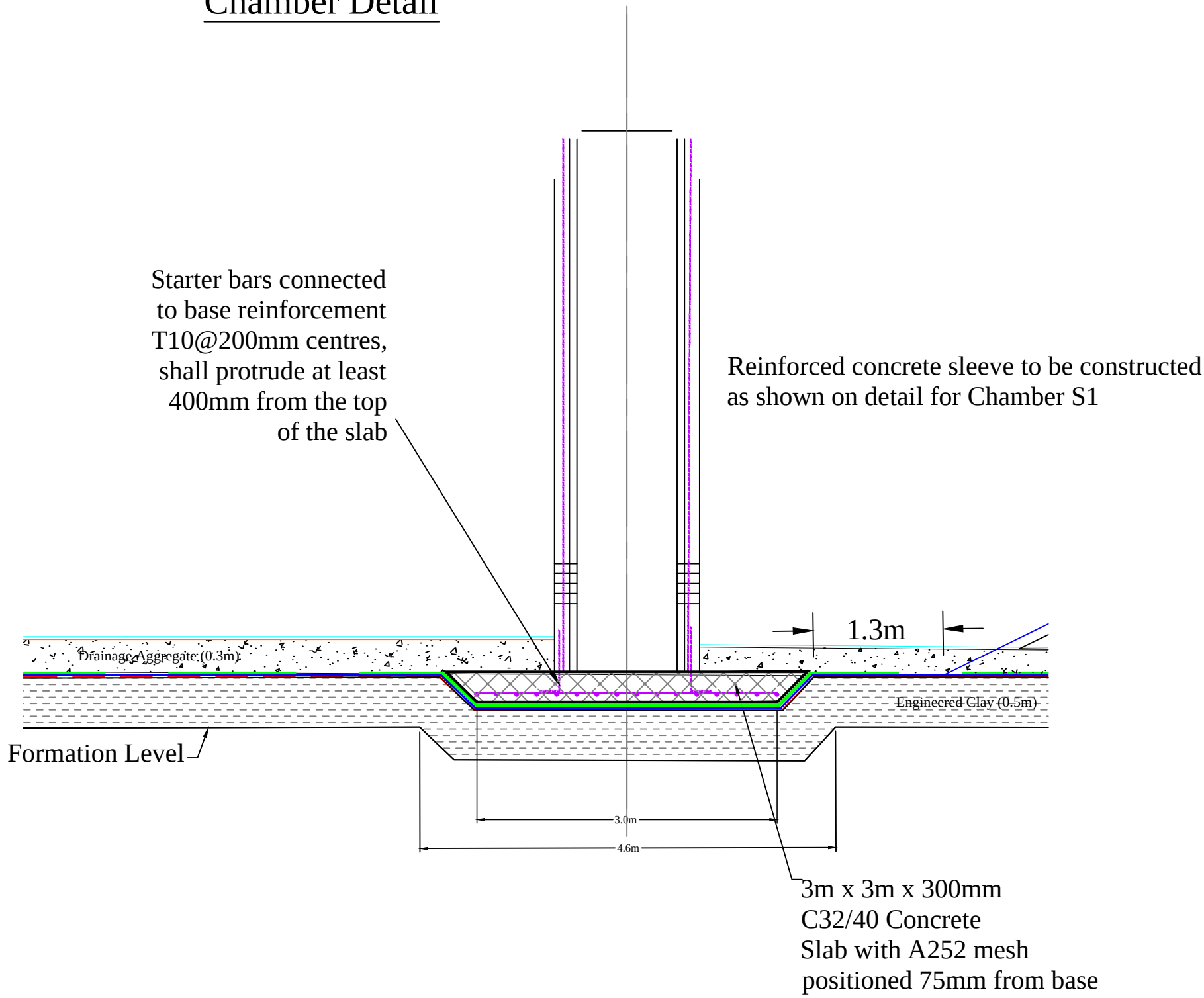


- Notes
- Plan Legend
- Top of Clay Contours (1 metre intervals, m OD)
 - Topography Dec 14 Contours (1 metre intervals, m OD)
- Section Legend
- Filter Geotextile
 - Protective Geotextile
 - HDPE FML
 - Geosynthetic Clay Liner (GCL)
 - Steel Reinforcement
 - Coloured Geotextile over target pad
 - Cell Formation

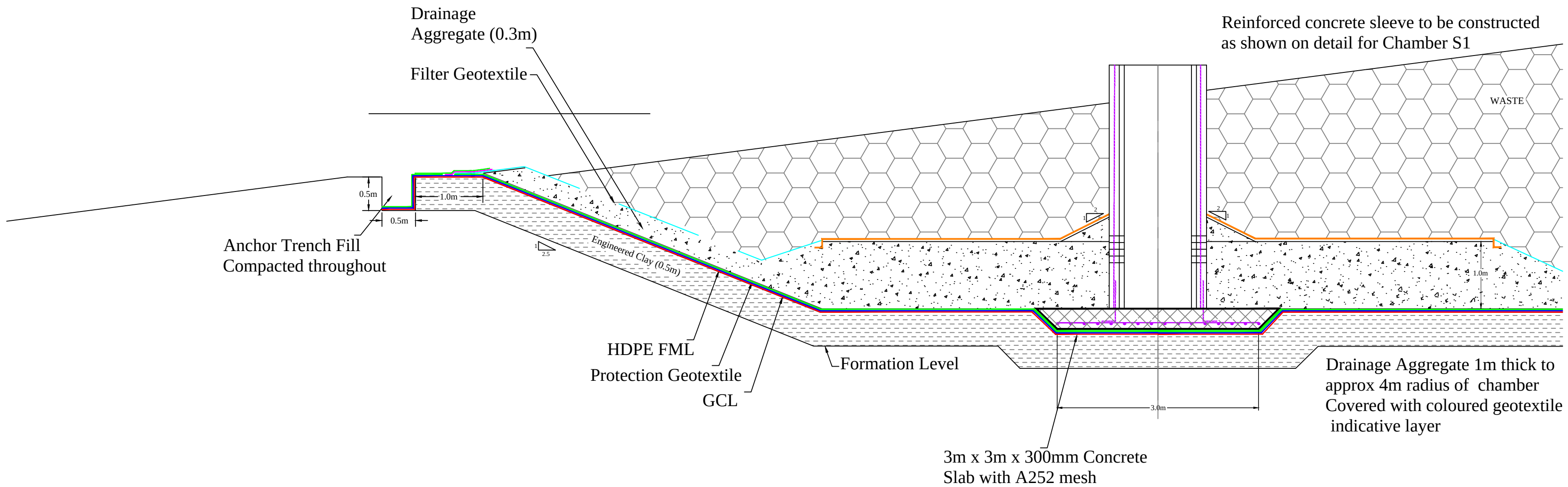


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PottersWasteManagement		
Site		
Withyhedge Landfill		
Title		
Long Section		
Scale	As shown	@ A1
Drawing No.	2185/2/005	
Rev	Date	Description
File	21852005longsection.dwg	
Date	01/15	Engineer JW
Drawn	PT	Checked DRAFT

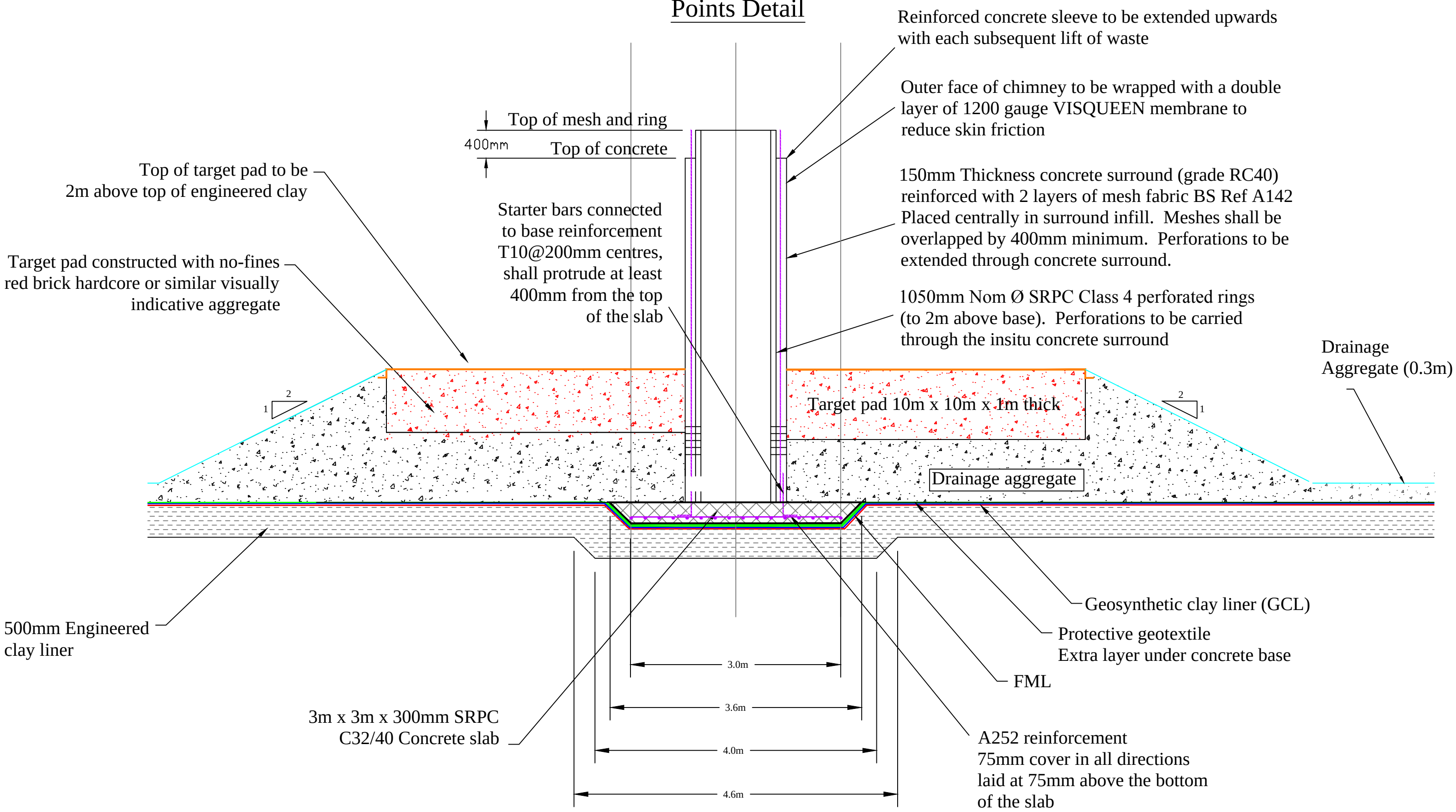
Valley Cell N2 & N3
Leachate Extraction
Chamber Detail



Valley Cell N1
Leachate
Extraction
Chamber Detail



Valley Cell S1 Leachate Extraction
Chamber and Leachate Monitoring
Points Detail



Notes

- Filter Geotextile
- Protective Geotextile
- Double Textured FML
- Geosynthetic Clay Liner (GCL)
- Steel Reinforcement
- Coloured Geotextile over target pad

- Sacrificial layer of GCL to be placed beneath all concrete slabs. Place under GCL layer. Omitted from drawings for clarity.
- Chamber located within target pad as shown on drawing 2185/2/004.
- Extra Layer of Protection Geotextile under concrete base

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Client



PottersWasteManagement

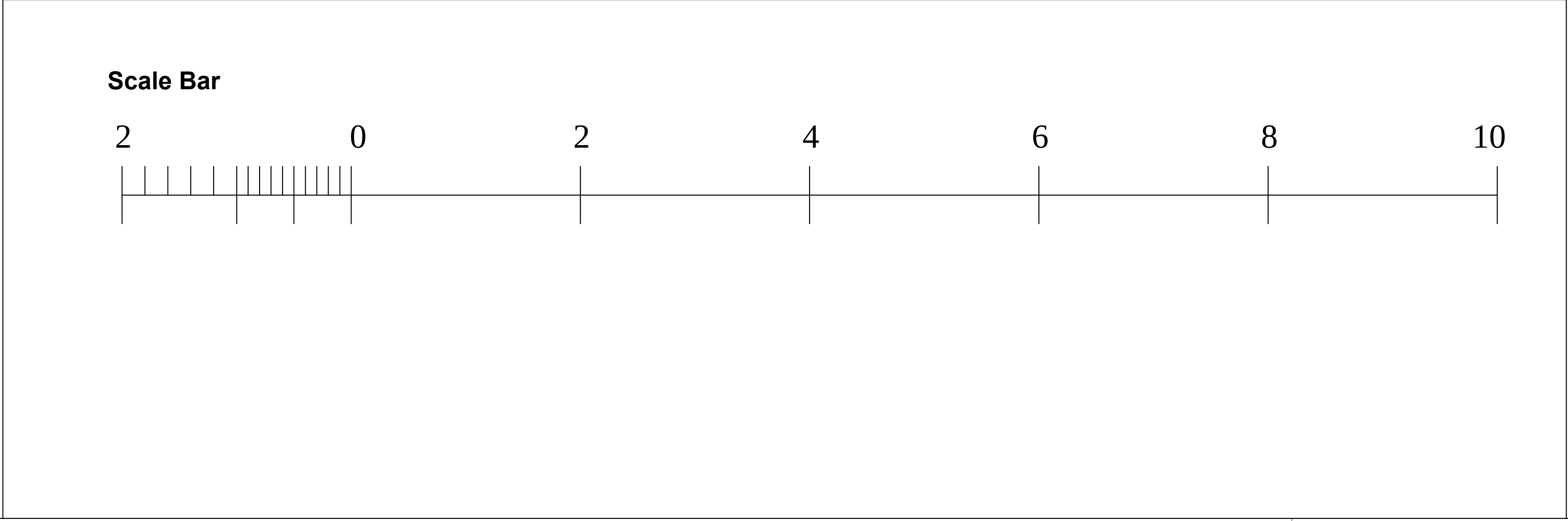
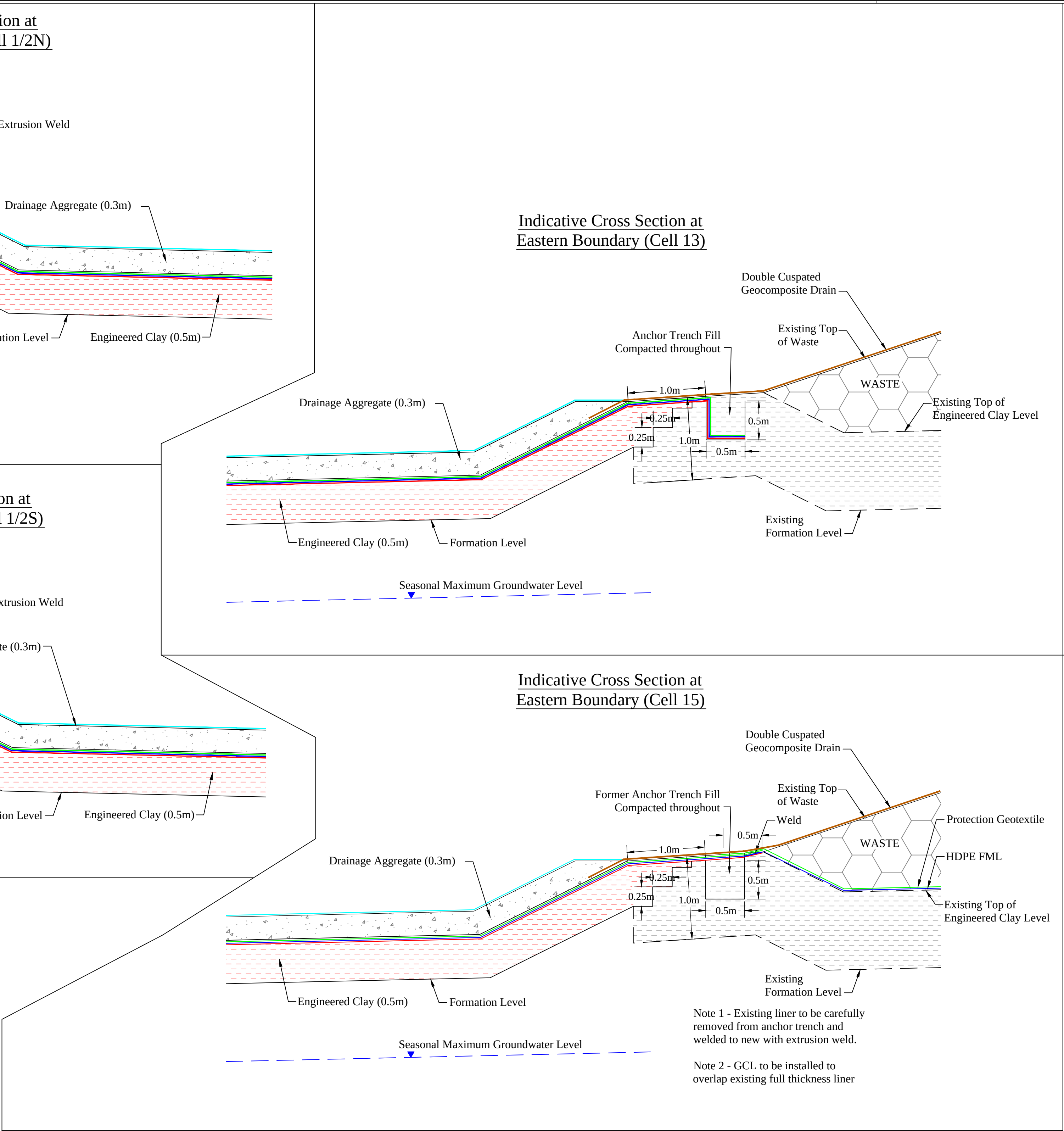
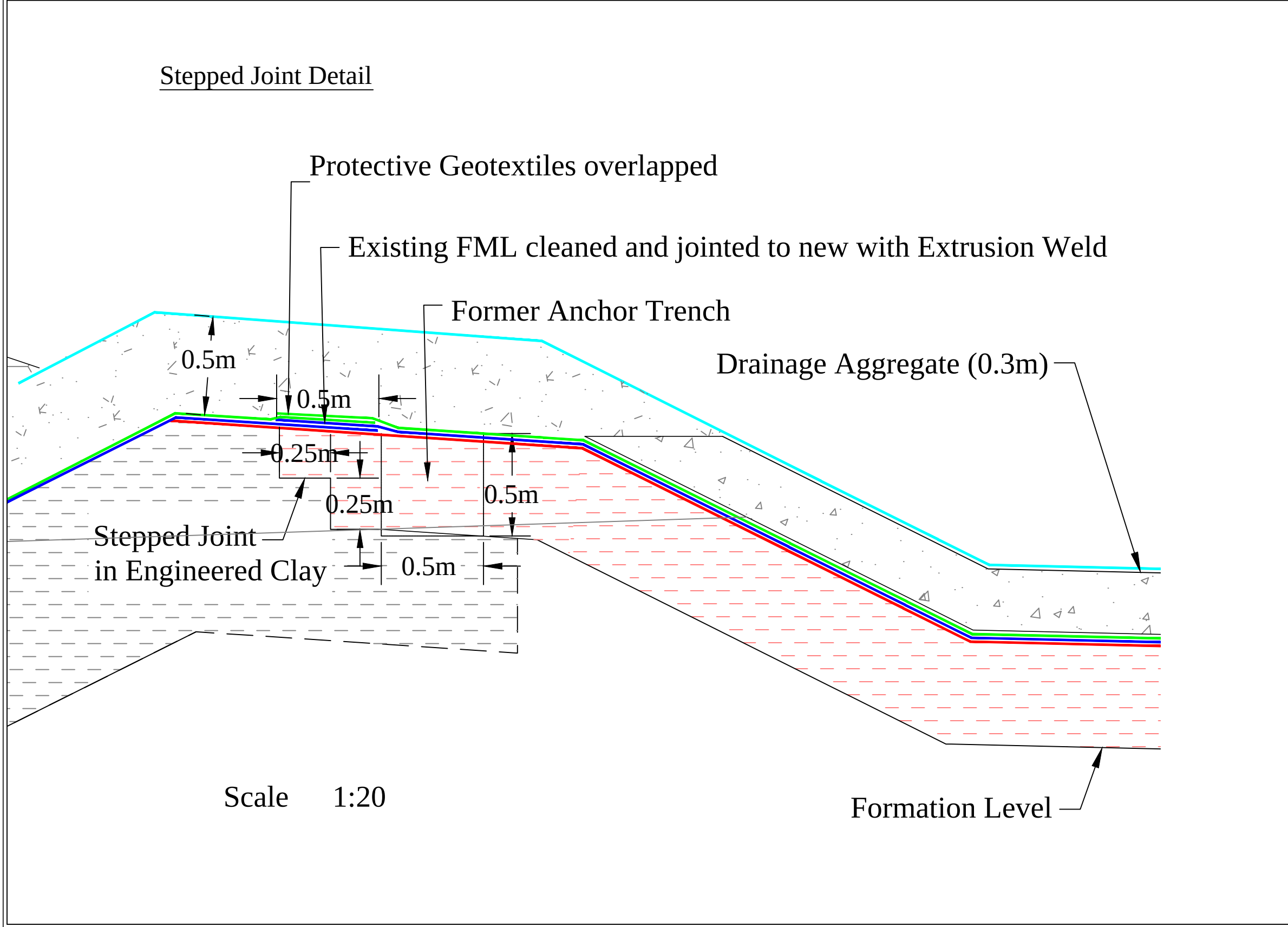
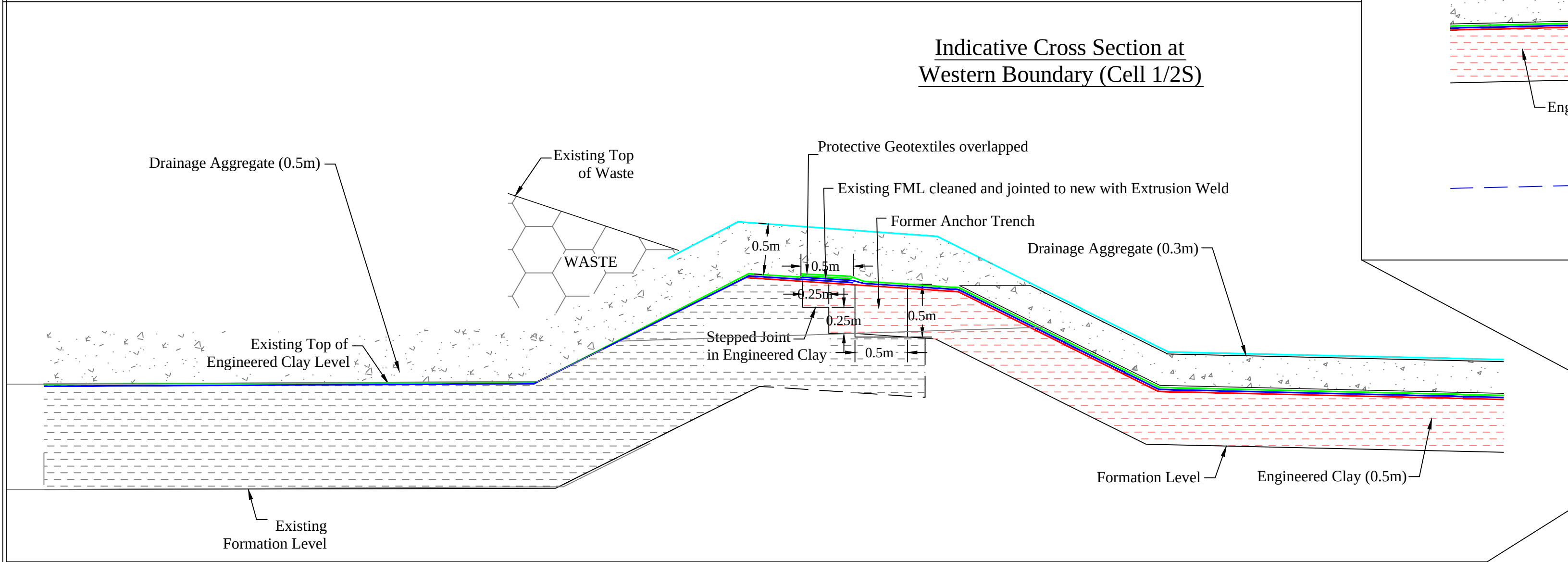
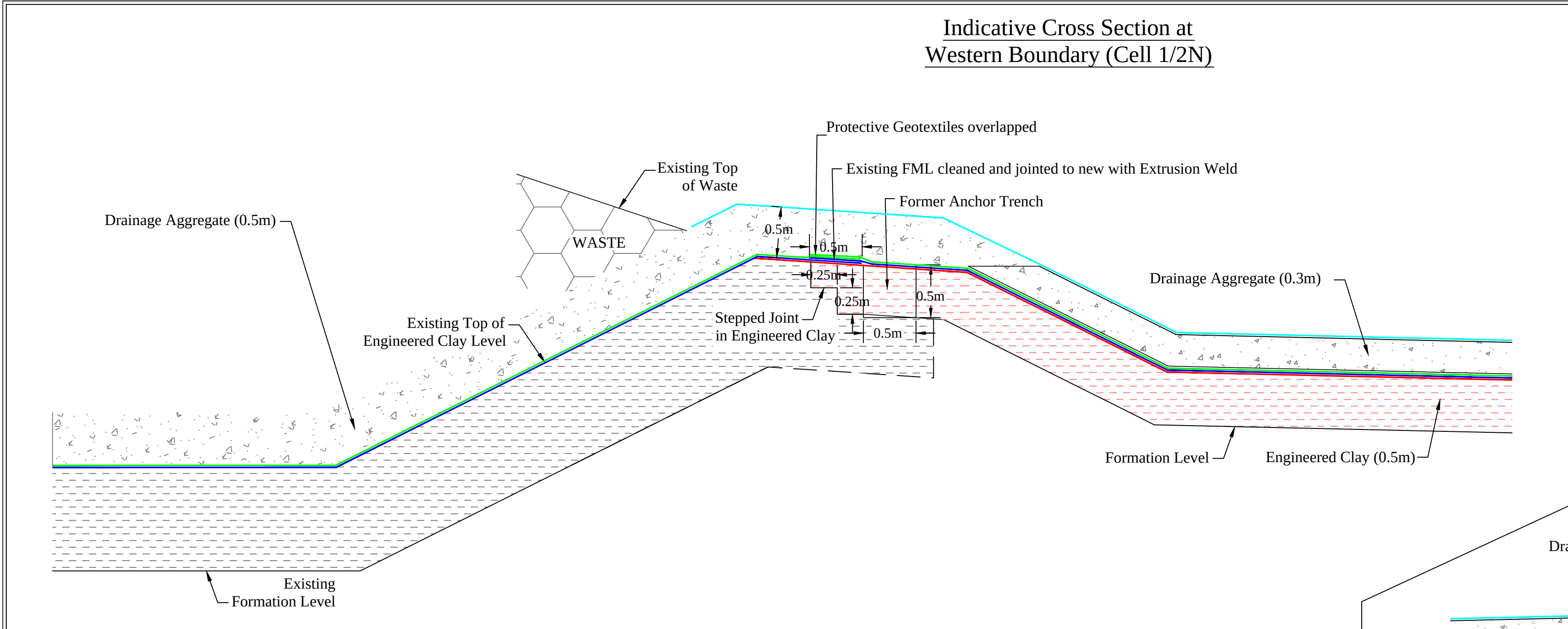
Site

Withyhedge Landfill
Valley Cells

Title

Leachate Extraction
Chambers

Scale	1:50	@ A1
Drawing No.	2185/1/006	
Rev	Date	Description
File	21851006LeachateExtractionChambers.dwg	
Date	02/15	Engineer JW
Drawn	PT	Checked DRAFT

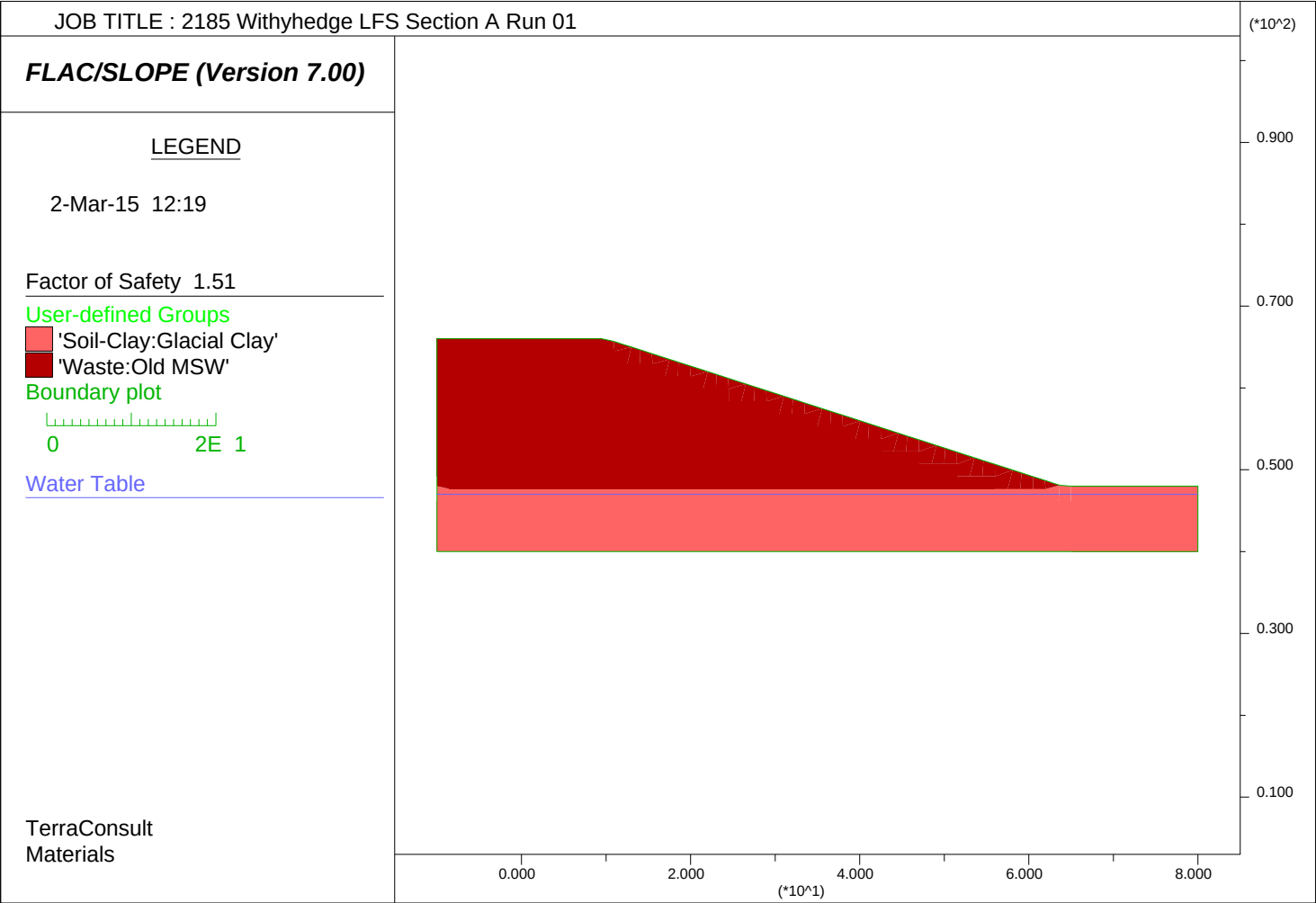


- Notes
- Section Legend
- Filter Geotextile
 - Protective Geotextile
 - Double Textured FML
 - Geosynthetic Clay Liner (GCL)
 - Geocomposite Drainage Layer
 - Max. Seasonal Groundwater level
- NB Transition from 0.5m thickness of drainage aggregate in Phase 1/2 N&S to 0.3m thickness of drainage aggregate in valley cells across western edge bund.

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PottersWasteManagement		
Site		
Withyhedge Landfill Valley Cells		
Title		
Cell Edge Details		
Scale	NTS	@ A1
Drawing No.	2185/2/007	
Rev	Date	Description
File	21852007edgedetails.dwg	
Date	02/15	Engineer JW
Drawn	PT	Checked DRAFT

Appendix A

Global Stability - FLAC/Slope outputs



Project file: 2185 Withyhedge LFS Section A Run 01.psl

Project title: 2185 Withyhedge LFS Section A Run 01

Material Properties - Mohr-Coulomb

Class Name	Density ρ	Cohesion c	Tension σ^t	Friction ϕ	Dilation ψ
Units	kg/m³	Pa	Pa	Deg.	Deg.
Waste New MSW	1000.0	4000.0	0.0	20.5	0.0
Waste Old MSW	1000.0	4000.0	0.0	20.5	0.0
Soil-Clay Glacial Clay	2000.0	1600.0	0.0	18.8	0.0

Interface Properties

Class Name	Cohesion Pa	Tensile Str Pa	Friction Deg.	Dilation Deg.
User new 1	0.0	0.0	0.0	0.0

Factor of Safety

Project	Model	Material Type	Shape	Mesh	Switches	FOS
2185	Withyhedge_LFS_Section_A_Run_01_Model_1	Mohr-Coulomb	General slope	Fine	fc	1.51

Program: FLAC/Slope v7.0.421 & GIIC/Slope v2.20.489

Created: Mon Mar 02 12:20:08 GMT 2015

JOB TITLE : 2185 Withyhedge LFS Section ARun 01

(*10²)

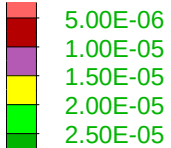
FLAC/SLOPE (Version 7.00)

LEGEND

2-Mar-15 12:17

Factor of Safety 1.51

Shear Strain Rate Contours



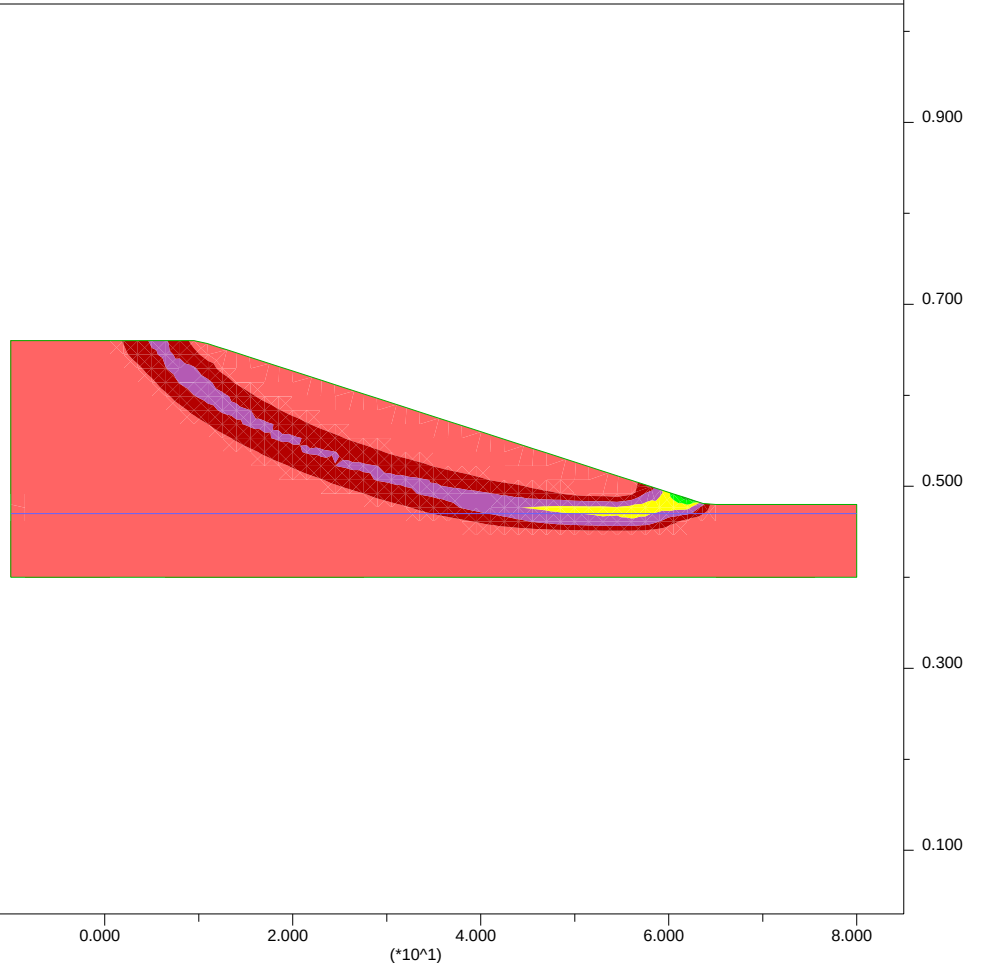
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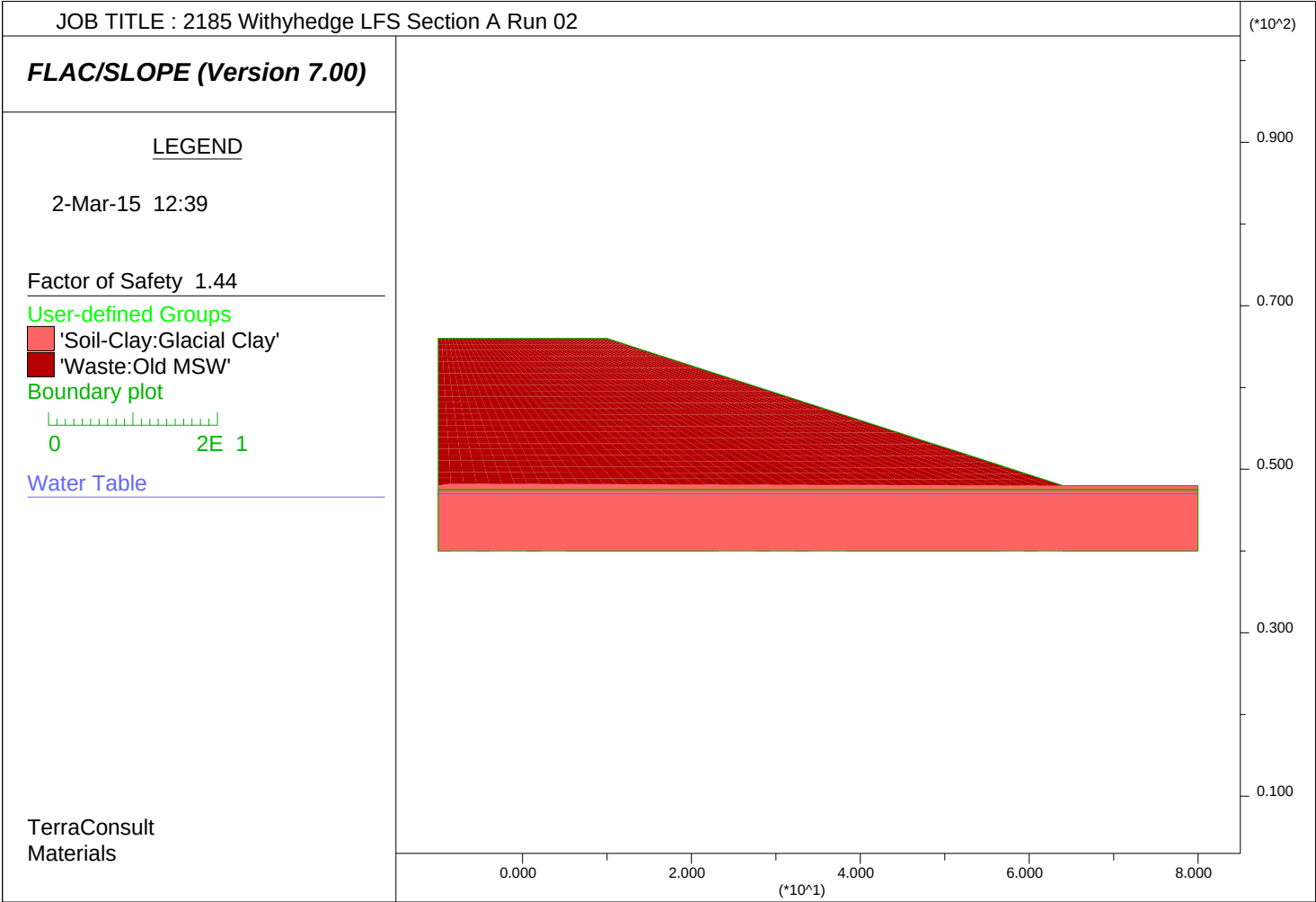
Boundary plot



Water Table

TerraConsult
Strains





Project file: 2185 Withyhedge LFS Section A Run 02.psl

Project title: 2185 Withyhedge LFS Section A Run 02

Material Properties - Mohr-Coulomb

Class Name	Density ρ	Cohesion c	Tension σ^t	Friction ϕ	Dilation ψ
Units	kg/m³	Pa	Pa	Deg.	Deg.
Waste New MSW	1000.0	4000.0	0.0	20.5	0.0
Waste Old MSW	1000.0	4000.0	0.0	20.5	0.0
Soil-Clay Glacial Clay	2000.0	1600.0	0.0	18.8	0.0

Interface Properties

Class Name	Cohesion Pa	Tensile Str Pa	Friction Deg.	Dilation Deg.
User GCL/ rough HDPE	0.0	20000.0	24.8	0.0

Factor of Safety

Project	Model	Material Type	Shape	Mesh	Switches	FOS
2185	Withyhedge_LFS_Section_A_Run_02_Model_1_Fine	Mohr-Coulomb	General slope	fc	i	1.44

Program: FLAC/Slope v7.0.421 & GIIIC/Slope v2.20.489

Created: Mon Mar 02 12:41:15 GMT 2015

JOB TITLE : 2185 Withyhedge LFS Section A Run 02

(*10^2)

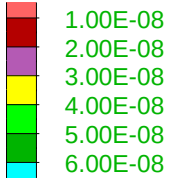
FLAC/SLOPE (Version 7.00)

LEGEND

2-Mar-15 12:40

Factor of Safety 1.44

Shear Strain Rate Contours



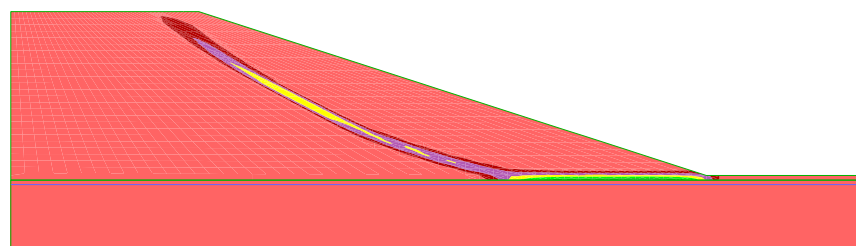
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Boundary plot

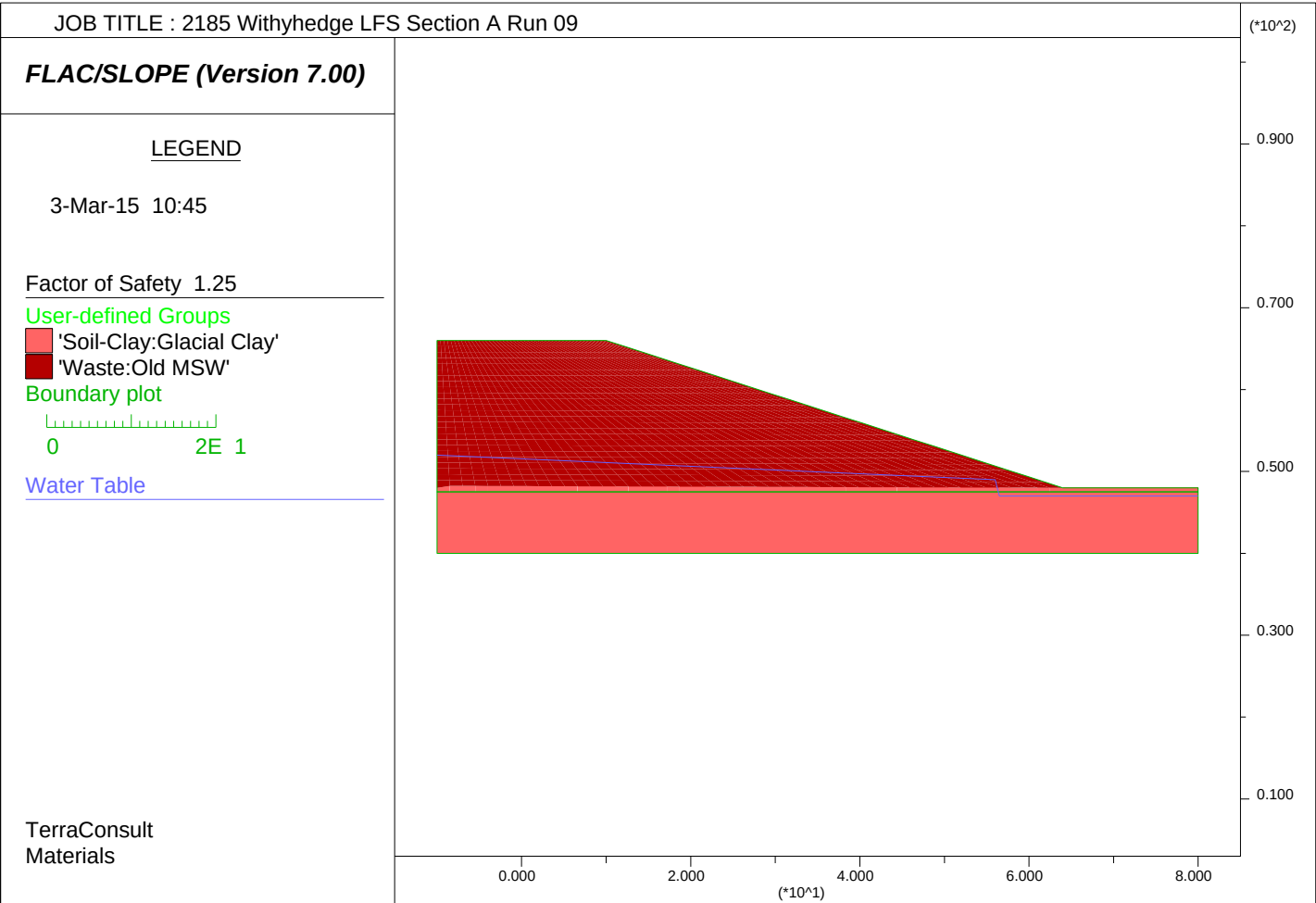


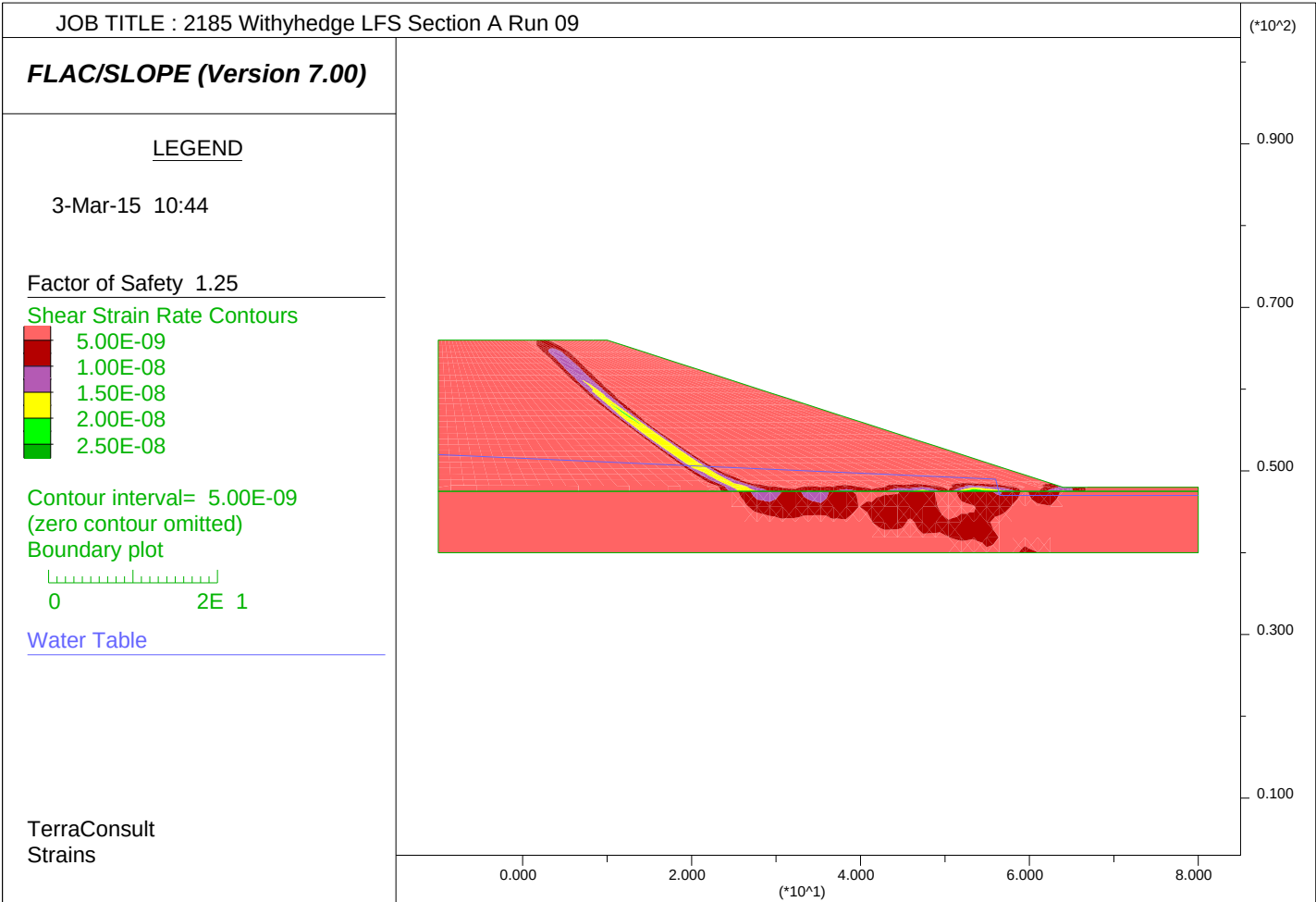
Water Table

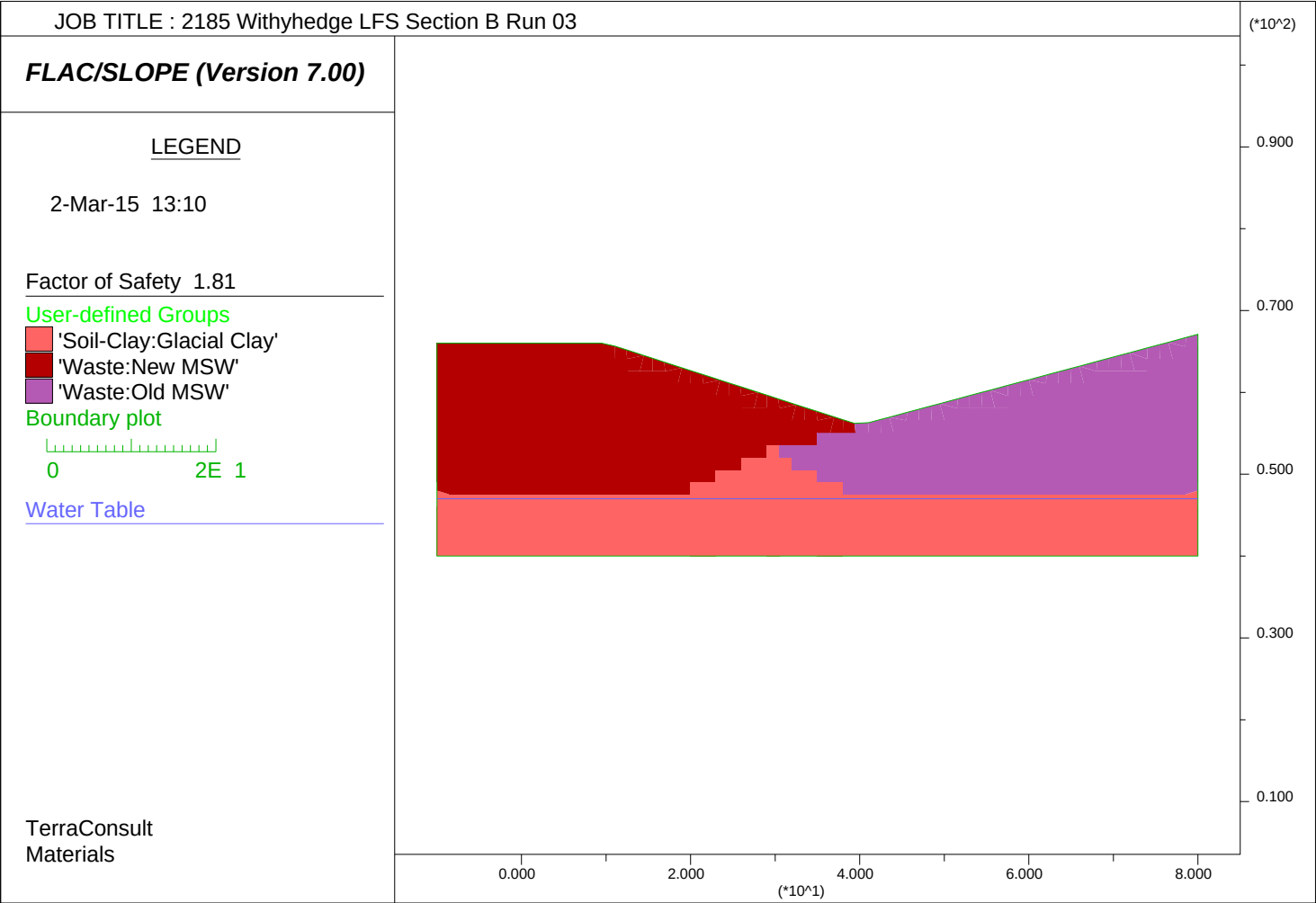
TerraConsult
Strains



0.000 2.000 4.000 6.000 8.000
(*10^1)







JOB TITLE : 2185 Withyhedge LFS Section B Run 03

(*10²)

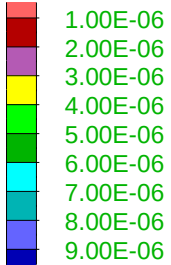
FLAC/SLOPE (Version 7.00)

LEGEND

2-Mar-15 13:09

Factor of Safety 1.81

Shear Strain Rate Contours



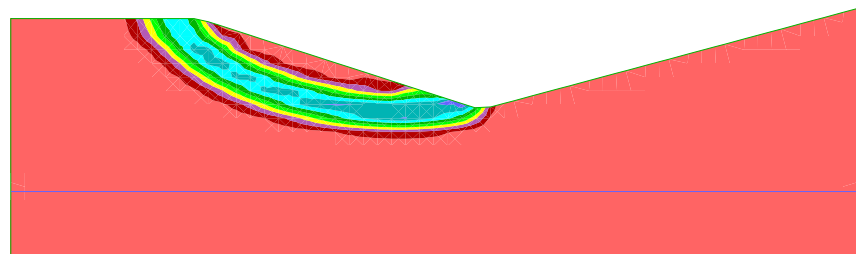
Contour interval= 1.00E-06
(zero contour omitted)

Boundary plot



Water Table

TerraConsult
Strains



0.000 2.000 4.000 6.000 8.000

(*10¹)

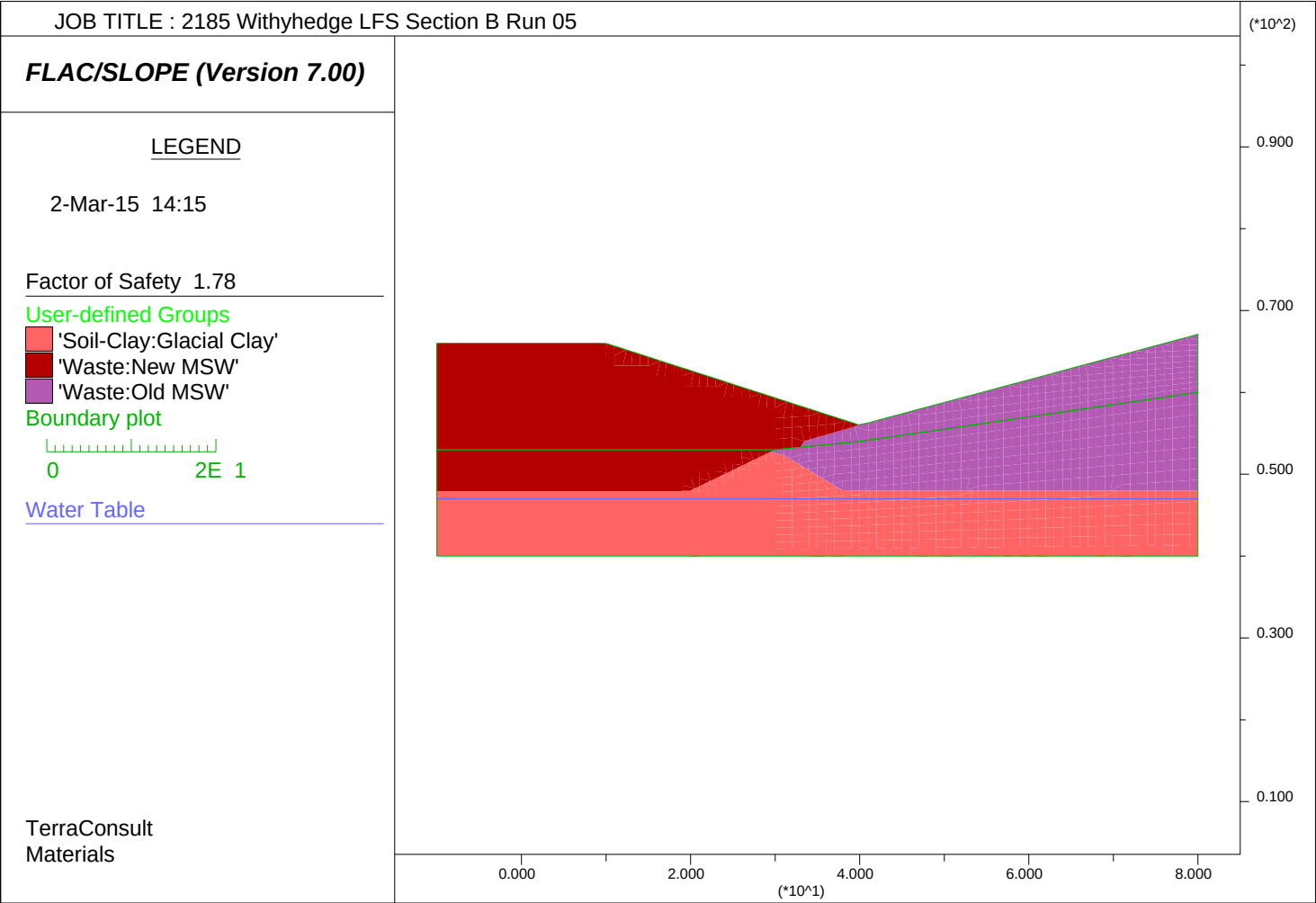
0.900

0.700

0.500

0.300

0.100



JOB TITLE : 2185 Withyhedge LFS Section B Run 05

(*10²)

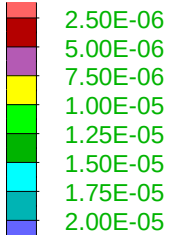
FLAC/SLOPE (Version 7.00)

LEGEND

2-Mar-15 14:14

Factor of Safety 1.78

Shear Strain Rate Contours



Contour interval= 2.50E-06

(zero contour omitted)

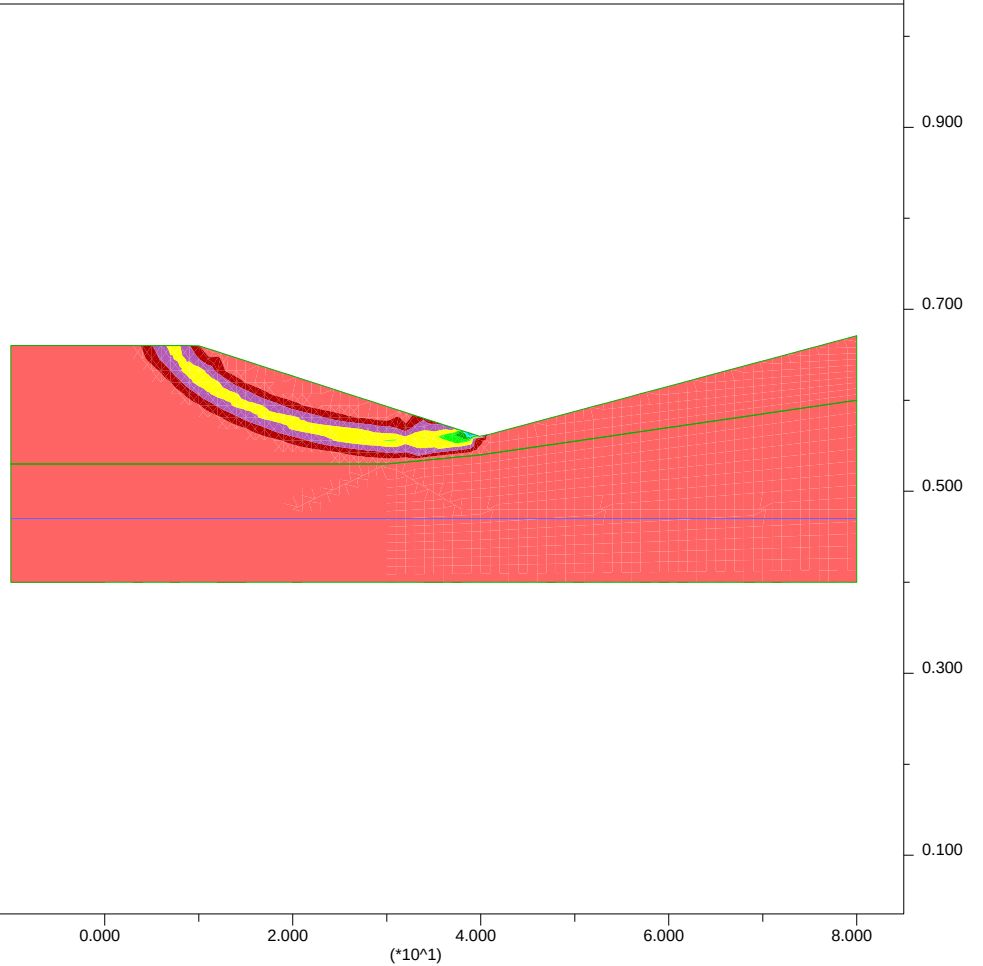
Boundary plot



0 2E 1

Water Table

TerraConsult
Strains



$(\cdot 10^2)$

LEGEND

0.900

0.700

■ 'Soil-Clay:Glacial Clay'

 exclude

Boundary plot



0.700

0.300



0.000 2.000 4.000 6.000 8.000
(*10⁴)

(*10^2)

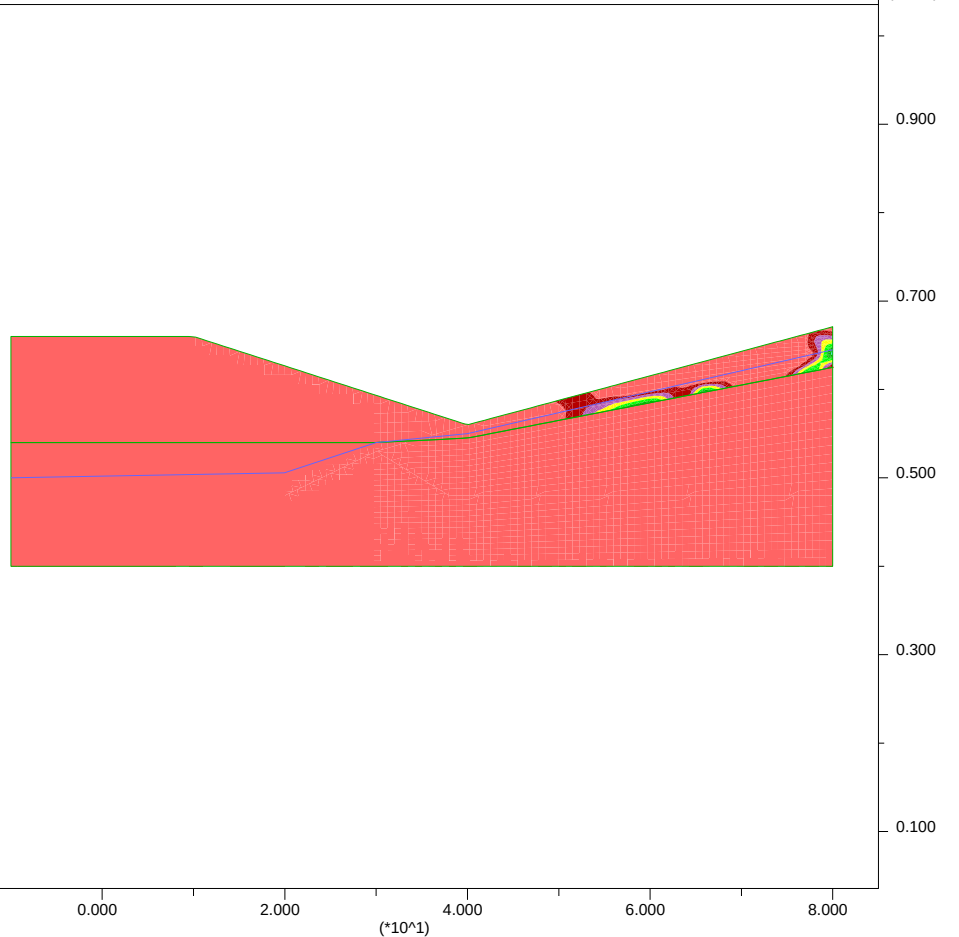
LEGEND

0.900

0.700



2432



Appendix B

Stability of Leachate Monitoring Point

Client: Potters Waste Management
 Project Name: Withyhedge Landfill Site Valley Cells
 Project No: 2185

Leachate Extraction Chamber - Base stability

See DrawingNo 2185/1/007

Height of waste above Top of clay	m	2	21
Thickness of target pad	m	1	1
Thickness of leachate drainage layer	m	0.5	0.5

Chimney

Internal diameter of chimney wall units	mm	1050	1050
Thickness of chimney wall units	mm	80	80
External diameter of chimney wall units	mm	1210	1210
Thickness of concrete surround to chimney	mm	150	150

Weight of chimney+ concrete surround	kN	20.4	150.0
Weight of leachate in chimney	kN	17.3	86.6

10 m rise in leachate

Chimney Base Unit

Weight of target pad + drainage stone over base slab area	kN	360.0	360.0
---	----	-------	-------

Concrete Base slab

Size of square concrete base slab	m	3.000	3.000
Thickness of concrete base slab	mm	300	300
Weight of concrete base	kN	67.5	67.5

Waste

Density of waste	kN/m ³	12.0	12.0
Cohesion of waste EC7 C2	kN/m ²	4.0	4.0
Angle of shearresistance of waste EC7 C2 ϕ degrees		20.8	20.8

Weight of waste on top of chimney base unit

Area A - Weight of waste	kN	64.4	676.6
Area B - Weight of waste	kN	29.8	595.2
Area C - Weight of waste	kN	0.0	612.2
Total weight of waste on top of chimney base unit	kN	94.2	1884.0

Negative skin friction by waste around perimeter of chimney

K _o value for waste		0.64	0.64
Vertical pressure at base of waste	kPa	24.0	252.0
Horizontal pressure at base of waste	kPa	15.36	161.28
Total negative skin friction	kN	26.3	2633.3
Reduction factor on Negative skin friction to allow for visqueen		0.30	0.30
Design negative skin friction	kN	7.9	790.0

$$(1 - \sin \phi) = 0.64$$

Full value
 Note : 1 = No reduction
 value allowing reduction

Out of balance horizontal thrust against chimney

Out of balance horizontal thrust against chimney	kN	18.6	20.6
--	----	------	------

use Ka = 0.33 and Kp = 3

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Client: Potters Waste Management
 Project Name: Withyhedge Landfill Site Valley Cells
 Project No: 2185

Height of waste above target pad	m	2	21
Lever arms for moments about Left Hand edge of base slab			
Chimney, Chimney base unit, Leachate, Concrete base slab	m	1.500	1.500
Waste - Area A	m	0.448	0.448
Waste - Area B	m	1.500	1.500
Waste - Area C	m	2.553	2.553
Waste - Negative skin friction	m	1.500	1.500
Waste - out of balance horizontal thrust against chimney	m	2.967	21.900
Moments about Left Hand bottom edge of base slab			
Chimney and concrete surround	kNm	30.7	224.9
Weight of concrete base	kNm	26.0	129.9
Target pad and drainage stone over base slab area	kNm	540.0	540.0
Concrete base slab	kNm	101.3	101.3
Waste - Area A	kNm	28.8	302.8
Waste - Area B	kNm	44.6	892.8
Waste - Area C	kNm	0.0	1562.6
Reduced negative skin friction	kNm	11.8	1185.0
Out of balance horizontal thrust against chimney	kNm	55.1	451.8
Total moment about LH bottom edge of base	kNm	838.3	5391.1
Total weight over base slab area kN			
Chimney and concrete surround	kN	20.4	150.0
Weight of leachate in chimney	kN	17.3	86.6
Target pad and drainage stone over base slab area	kN	360.0	360.0
Concrete base slab	kN	67.5	67.5
Waste Total	kN	94.2	1884.0
Reduced negative skin friction	kN	7.9	790.0
Out of balance horizontal thrust against chimney	kN	0.0	0.0
Total weight over base slab area	kN	567.4	3338.1
Eccentricity of resultant force from centre of base	m	-0.022	0.115
Maximum foundation pressure (kPa) =		65.9	456.2
Minimum foundation pressure (kPa) =		60.2	285.6

B/6 (m) = 0.500

Bearing Capacity of foundation considering deep clay subgrade		Short term	Long term
Unit weight of subgrade		20	20
Angle of friction of the subgrade EC7C2 ϕ degrees		0.0	18.8
N_c		5.14	13.10
N_q		1.00	5.30
N_γ		0.00	2.10
Cohesion of subgrade EC7C2	kPa	35.7	1.6

Barnes Table 8.5
 Barnes Table 8.5
 Barnes Table 8.5

Client: Potters Waste Management
 Project Name: Withyhedge Landfill Site Valley Cells
 Project No: 2185

		Short term		2 m waste	Barnes Eqn 8.3
Overburden pressure at fnd level p_o kPa		24			
Ultimate capacity					

Bearing Capacity of foundation considering thin clay subgrade with short term loading

Thickness of clay stratum m	0.5	d	OK < clay layer is thin
Foundation ratio	6	B/d	
NetUltimate capacity kPa	219		
ODF against shear failure based on undrained strength for 2 m of waste	3.7	OK - safe	

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Client: Potters Waste Management
Project Name: Withyhedge Landfill Site Valley Cells
Project No: 2185

Leachate Extraction Chamber concrete base design to BS8110		See DrawingNo 2185/1/007	
Height of waste above Top of clay	m	2	21
Maximum foundation pressure (kPa)		65.9	456.2
Minimum foundation pressure (kPa)		60.2	285.6
Size of square concrete base slab	m	3.000	3.000
Thickness of concrete base slab	mm	300	300
External diameter of chimney wall units	mm	1210	1210
Length of Base slab Cantilever	m	0.895	0.895
Reduced pressure at face of chimney concrete surround	kNm ²	64.2	405.3
Weight of waste, target pad, drainage stone over base slab area kN		425.9	1678.8
Overburden pressure on base slab	kN/m ²	47.3	186.5
Shear force at face of chimney concrete surround	kN	59.9	57.3
Bending Moment at face of chimney concrete surround	kNm	39.5	50.4
Concrete design to BS8110			
Cover to reinforcement	mm	75	75
Diameter of tensile reinforcement	mm	8.0	8
Area of tensile reinforcement per metre width of slab	mm ²	252.0	252
Cube strength of concrete	N/mm ²	32.0	32
Effective depth of concrete section	mm	221	221
	K	0.008	0.011
K' for no moment redistribution		0.156	0.156
Compression reinforcement is not required			
z		218.9	218.3
0.95d		210.0	210.0
value of z to use in calculation		210.0	210.0
Area of tension steel required per metre width of slab	mm ²	143.5	183.2
calculated design shear stress	N/mm ²	0.090	0.086
100 A _s /bd		0.114	0.114
design shear stress from Table 3.8	N/mm ²	0.390	0.390

Allowing for arching in waste

A252 square mesh
A252 square mesh

OK OK

OK OK

APPENDIX E

LEACHATE LEVEL CALCULATIONS

Bold Business Centre
Bold Lane, Sutton
St. Helens, Merseyside
WA9 4TX

Telephone: +44 (0) 1925 291111 Fax: +44 (0) 1925 291191
e-mail: mailbox@terraconsult.co.uk Website: www.terraconsult.co.uk

Our Ref: 2185/L/001

10th March 2015

**For the attention of David Williams
Potters Waste Management**

Potter House
Henfaes Lane
Welshpool
Powys
SY21 7BE

Dear David,

**WITHYHEDGE LANDFILL SITE
EPR/BP3131SG/V005: Table S1.4B Pre-Operational Measure Reference 3**

Further to your email dated 9th December 2014 to Jim Waterworth (TerraConsult), please see below our proposed response to address pre-operational measure reference 3 of the above permit. The pre-operational measure requires the operator to:

'Prior to the engineering and deposit of wastes in the valley area between Phase 1 and 2...The operator shall review the existing leachate management system and leachate levels within Cells 1 and 2 North and provide written confirmation, with justifications, to demonstrate to the Agency [Natural Resource Wales] that there is sufficient capacity within the existing cell to receive additional leachate (overflow) from the northern valley cell as proposed without causing any risk to surface or groundwater receptors or breach of permit limits'.

Leachate Storage Capacity of Cells N1, N2 and N3

The approved water balance calculations (2008 permit variation Technical Standards document referenced WHV1-4) demonstrate that there will be sufficient absorptive capacity in the waste deposits in North Valley cells (N1, N2 and N3) to absorb all rainfall until capping starts after 6 months of the commencement of filling. Any leachate that does reach the drainage blanket will be removed by the 3 pneumatic / eductor type pumps. It is likely there will be a minimal standing head of leachate in the Valley cells for the short period of time the waste is uncapped.

This scenario assumes a consistent rate of rainfall based on the annual average. For conservatism an assessment has been made on the possible impact of two scenarios:

1. Rainfall from a storm event (0.075m) entering the northern valley cells with no standing head of leachate; and,
2. Rainfall from the same storm event entering the northern valley cells when the standing leachate head is already at the invert of the overflow pipe.

Scenario 1. Valley Cells Empty of Leachate

The worst case scenario for this assessment is that all the northern valley cells (sequenced south to north as N3, N2 and N1) contained waste but are not capped. This means any rainfall which lands in the valley cells will be classified as landfill leachate and will require management as such. It is assumed the storm event will occur before the North Cells are capped. The adjacent Cell 1 North is already capped and less likely to be affected by such a high rainfall event. It is assumed there is no standing head of leachate in the valley cells due to the absorptive capacity of the fresh wastes and routine removal by the operator.

It is assumed that the drainage blanket represents the main storage capacity of the cells with a void space of 25%. A nominal waste depth of 3m is assumed in all cells. The likely porosity of the waste can be calculated using data from Powrie and Beavan¹. The porosity of freshly deposited waste with an assumed 3 tonne load above is 15% (assumes 1 tonne waste / m³). This porosity will apply from the top of the drainage stone to an elevation equivalent to the crest of the intra-cell valley bunds and overflow point into Cell 1 North.

For conservatism and simplicity, the storage capacity of cells N1, N2 and N3 does not include the waste placed on the diagonal slopes outwards from the edge of the flat drainage stone area. The leachate storage capacity of cell N3 on this basis is 118m³ and cells N1 and N2 combined is 129m³. The total leachate storage capacity of Cells N1, N2 and N3 before leachate can overflow into Cell 1 North is 247m³.

The plan surface area of Cells N1, N2 and N3 is 3,629m². This includes the side slopes rising outwards from the drainage blanket. A 24 hour 100 year return storm event (+ 30% for climate change) will produce 0.071m of rain will result in 257m³ of leachate forming within the north valley area. For the purposes of this assessment it is assumed there is no remaining absorptive capacity in the waste (only the 15% void space) and all rainfall will immediately soak through the waste and into the empty drainage blanket. In reality a proportion of the rainfall will be absorbed into the waste and it would take several hours for it to percolate downwards into the drainage blanket.

The northern valley cells will be installed with 3 x 1 m³/hr capacity pneumatic / eductor pumps capable of removing up to 72m³ of leachate over 24 hours. This would reduce the volume of leachate in the 3 northern valley cells to 185m³. Therefore there would be 62m³ spare storage capacity in the Valley (247m³ – 185m³) and no leachate would overtop into Cell 1 North. It would take 2.6 days to remove this volume of leachate from the cell completely.

¹ Powrie and Beavan, 1999. Hydraulic Properties of Household Waste and Implications for Landfills.

Scenario 2: Valley Cells containing leachate to overtop level.

The calculations used in Scenario 1 still stand. In this scenario it is assumed all 257m³ of leachate potential generated in a storm event overtops into Cell 1 North.

The lowest liner elevation of Cell 1 North is 44.5 mOD. The lowest crest elevation of the perimeter bund at the north boundary is 46.6 mOD. This equates to a freeboard of 2.1m before leachate could potentially overtop the bund. The leachate compliance limit in this cell is 1m above base and assuming this head is maintained there will be 1.1m of unsaturated waste available. In reality the site consistently maintains a leachate head of 0.9m.

The depth of waste in Cell 1 North ranges from around 2m to 12m (based conservatively on the lowest liner elevation to the north and current maximum pre-settlement level). The porosity of waste with an assumed 12 tonne load above is 7% (assumes 1 tonne MSW / m³). The porosity of waste with at least a 2 tonne load is at least 15% giving an average basal waste porosity across the cell of 11%. For conservatism the lowest porosity of 7% will be used.

The plan area of leachate within the waste / drainage blanket in Cell 1 North at a 1m head is 3,060m². The plan area of leachate at a 1.2m head i.e. overtop point of the bund is 7,510m². The average area is 5,285m² giving a volume of unsaturated waste at 6,342m³. The storage capacity of this waste at 7% is 444m³.

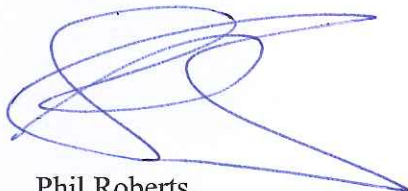
Assuming leachate levels in Cell 1 North are kept at 0.9m, if the additional leachate generated from a storm event (minus the volume removed by the 3 pumps) were to overtop from the valley cells it could raise the leachate head in Cell 1 North by 42% (approximately 0.5m) at a porosity of 7%. It would take around 7.7 days to remove this extra leachate.

This worst-case assessment suggests that:

- Significant volumes of leachate are unlikely to accumulate in the valley cells due to the absorptive capacity of the fresh waste. Controlling any leachate that does accumulate should be very manageable.
- Leachate is unlikely to overtop into Cell 1 North from the valley cells even after a storm event, if leachate levels are maintained at compliant levels / minimised on an ongoing basis.
- If leachate levels are not minimised, there should be sufficient capacity in the adjacent Cell 1 North to accommodate the leachate even at the lowest likely porosity without it overtopping across the northern perimeter bund.
- If all the leachate derived from a storm event were to flow into Cell 1 North (minus that removed by pumping in the Valley Cells) it should be possible to bring the levels to below compliance within 7.7 days. The shore time frame suggests a detrimental emission to groundwater through the base of site is unlikely.

We hope you find the above satisfactory. Please do not hesitate to get in touch if you have any questions or comments relating to this response.

Yours sincerely
for and on behalf of TerraConsult Ltd



Phil Roberts
Principal Consultant

APPENDIX F

DRAWINGS

2185/2/001		Cell Location
2185/2/002		Cell Formation
2185/2/003		Top of Engineered Clay & Leachate Management Plan
2185/2/004		Waste Placement Phasing
2185/2/005		Long Section
2185/2/006		Leachate Extraction Chambers
2185/2/007		Liner Edge Details
2185/2/008		Leachate Overflow Details – Drawing deleted
2185/2/009		Cell 13 Leachate Chamber

APPENDIX G

EXAMPLE CQA RECORDS

Staff Member		Day/Date	
Client	Potters Waste Management	Site	Withyhedge Landfill Site
Project			
Weather			
List of Visitors			
1.	2.	3.	4.
5.	6.	7.	8.

Details of Site Work and CQA Work :

Progress / Works Completed

CQA Testing

Problems Encountered

Miscellaneous Plant and Workers Used

	<u>Position</u>	<u>On Site</u>		<u>Contract Personnel</u>	<u>Position</u>	<u>On Site</u>
Martin X	Surveyor	All day		Paul X	Operations Manager	1 day
Stuart X – Roller	Labourer	All day				
Driver	Foreman	All day				
Billy X						

<u>Plant</u>	<u>Area Working in</u>	<u>Hours worked</u>	<u>Standing</u>	<u>Breakdowns</u>
Excavator E340	Quarry Fines Stockpile 2 then 1	07:00-18:00	2hr	
Dozer D65	Waste north side	07:00-18:00		
Dozer D61	PPC Bund	07:00-18:00	2hr	
Dump Truck A25	Haul to ppc bund	07:00-18:00	2hr	
Dump Truck A25	Haul to ppc bund	07:00-18:00	2hr	
Dump Truck A25	Haul to ppc bund	07:00-18:00	2hr	
Dump Truck A25	North side waste	07:00-13:30	-----	
Komatsu Pc210 Excavator	North side waste	07:00-17:30		
Smooth drum vibratory roller	PPC Bund	07:00-18:00		

No Roller driver available until 09:00hrs

Staff Member		Week Ending	
Client		Site	
Project			

Weekly Report



NON-COMPLIANCE RECORD

CQA Form 3

SITE :

JOB No :

DATE :

CQA INSPECTOR :

Non-Compliance With :	Reason for Non-Compliance :	Action taken :	Remarks :

Temporary Groundwater Management System - Trial Pit Record

Site:

Job No :

Project:

Engineer:

Material:

Date	Trial Pit No.	Measured Thickness (mm)	Required Thickness (mm)	Material Description	Comments
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				

Clay Liner SUBGRADE APPROVAL RECORD

SITE :	DATE :
JOB NO :	CQA INSPECTOR:

Clay Liner Panel Reference	Remedial Works Completed :	Time of Day Approved :	Remarks :

Site: Withyhedge Landfill Site

Job No.

Location:

OPERATOR: S LELUAN

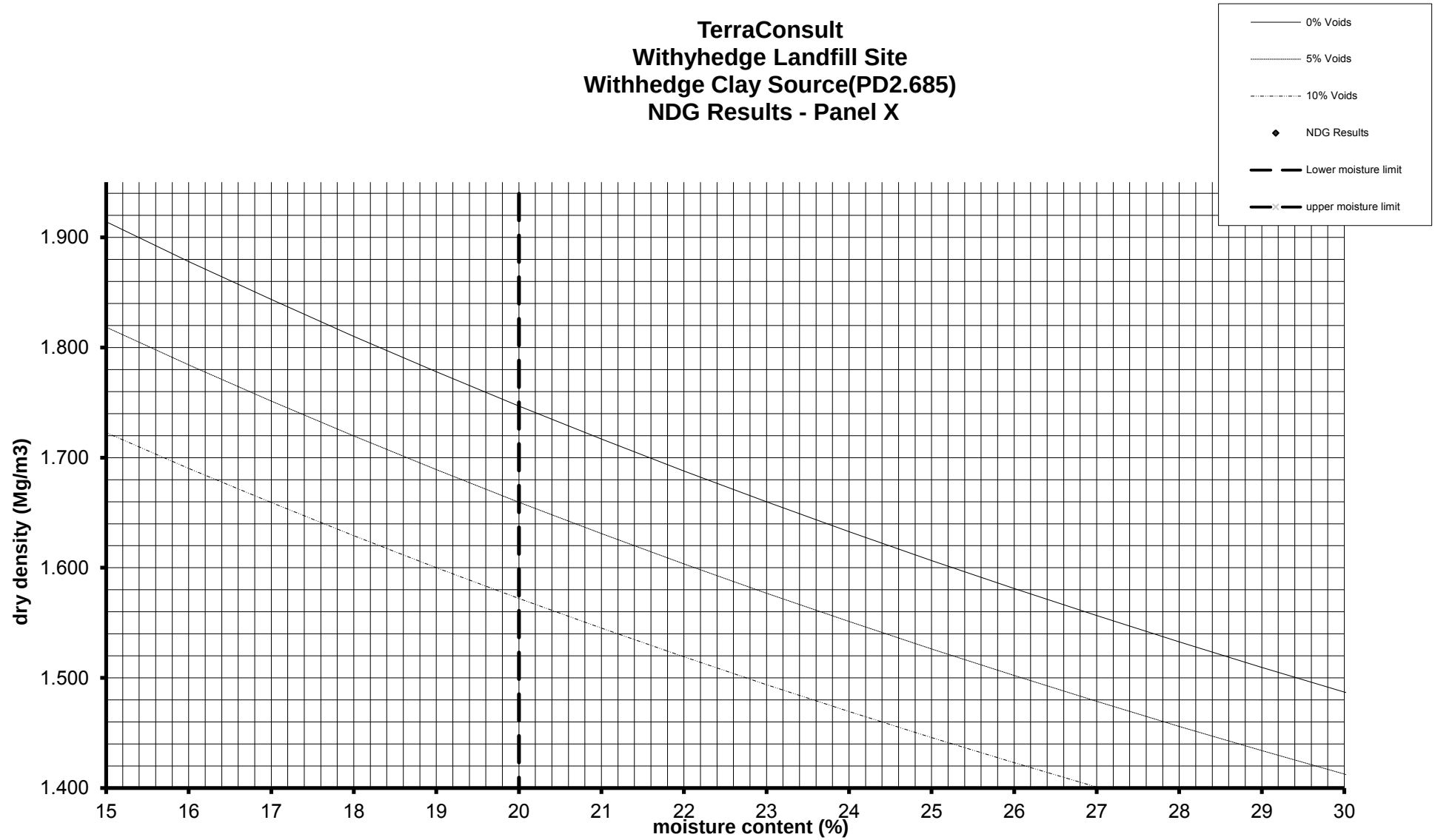
Density Factor 1.00

Moisture Factor	1.00
-----------------	------

Corrected Results

[illegible]

TerraConsult
Withyhedge Landfill Site
Withhedge Clay Source(PD2.685)
NDG Results - Panel X



5 NDG Records

Site: Withyhedge Landfill Site

Job No: _____

Location: _____

Engineer: _____

Material:

Roller:

[illegible]



HAND VANE - SHEAR STRENGTH RECORD TEST

Site: Withyhedge Landfill Site

CQA Form 8

Job No :

Engineer:

Surface Tested

[illegible]



CQA Inspector:

Site:

Job No:

GCL Delivery Record

[illegible]

GCL SUBGRADE APPROVAL RECORD

SITE :	DATE :
JOB NO :	CQA INSPECTOR:

Clay Liner Panel Reference	Remedial Works Completed :	Time of Day Approved :	Remarks :



CQA Inspector:

Site: _____

Job No. _____

GCL Deployment

[illegible]

GCL Deploy

[illegible]



CQA Form 13

CQA Inspector:

Site:

GCL Defects / Repair Record

[illegible]

Job No:

[illegible]

Withyhedge Landfill Site Lining Works**Subgrade Release Form**

Date:	Site:
Job No.	CQA Plan Reference:
Contractor:	

Subgrade Surface Inspected	
Area / Panel of Subgrade Inspected	
Time of Acceptance	

I the undersigned, a representative of TerraConsult Ltd, have visually observed the subgrade described above and confirm the subgrade is an acceptable surface upon which to install the

This certification is based on observation of the surface of the subgrade only. No subterranean inspections or tests have been performed by TerraConsult Ltd, and TerraConsult Ltd makes no representations or warranties regarding the conditions which may exist below the surface of the subgrade.

TerraConsult Representative	
Name:	Signature:
Date:	Position:

Site:

Job No.

FML Deployment Record

[illegible]

Site: _____ **Job No.** _____

Job No.

FML Trial Seam Summary

[illegible]

Failure code to be reported using the codes given at the rear of Appendix B to the CQA Method Statement

FML Fusion Welded Seam Construction and Destructive Testing Record

[illegible]

Site:**Job No.**

FML Non Destructive Seam Testing Record

[illegible]

* For air pressure test for hot wedge only
High Voltage Electrode for extrusion weld



FML Defects / Repair Record

CQA Inspector:

Site:

CQA Form 21

Job No:

[illegible]

Geotextile Deployment Record

[illegible]

Geotextile Defects / Repair Record

Site:

Job No:[illegible]

Leachate Chamber / Monitoring Point Construction Check List

Chamber/ Monitoring Point Reference

GENERIC

	Action / Check Item	Date Task Completed
	Leachate Chamber	
1	Designated area marked out	
2	Clay liner sump formation prepared with correct sidewall gradients and dimensions	
3	Thickness of clay liner compliant	
4	FML to chamber integral with the main FML - installed correctly and fully CQA'd	
5	Protective geotextile - installed correctly and fully CQA'd	
6	Additional protective geotextile (2nr layers) installed above main protective geotextile layer	
7	Concrete slab poured to correct level, using correct grade of concrete, with correct reinforcement	
8	Concrete cube samples collected by Contractor; results compliant with Spec.	
9	Concrete slab given smooth finish and flush with surrounding clay liner / weather protection layer	
10	Correct perforated base telescopic shaft unit supplied and installed correctly	
11	Gravel exclusion ring in place and correctly installed; clean of all contamination within the area of the ring	
12	Base 2-way pipe union installed with correct diameter pipe connection fittings and aligned correctly to leachate drainage pipe layout	
13	Leachate drainage stone layer set out correctly to achieve 1.5m x 1.5m from top surface corner	
14	Leachate drainage stone layer thickened to 1m under Target Pad	
15	Clean brick hardcore used and placed at correct thickness and dimensions as target pad	
16	Verticality checked after installation of the basal unit and surrounding aggregates	
17	Photographic record kept of each construction stage	
18	Correct first extension unit supplied to site and stored in accordance with manufacturer's guidance	
	Leachate Monitoring Points	
1	Designated area marked out	
2	Clay liner sump formation prepared with correct sidewall gradients and dimensions	
3	Thickness of clay liner compliant	
4	FML to chamber integral with the main FML - installed correctly and fully CQA'd	
5	Protective geotextile - installed correctly and fully CQA'd	
6	Additional protective geotextile (2nr layers) installed above main protective geotextile layer	
7	Concrete slab poured to correct level, using correct grade of concrete, with correct reinforcement	
8	Concrete cube samples collected by Contractor; results compliant with Spec.	
9	Concrete slab given smooth finish and flush with surrounding clay liner / weather protection layer	
10	Correct perforated base telescopic shaft unit supplied and installed correctly	
11	Gravel exclusion ring in place and correctly installed; clean of all contamination within the area of the ring	
12	Leachate drainage stone layer set out correctly to achieve 1.5m x 1.5m from top surface corner	
13	Leachate drainage stone layer thickened to 1m under Target Pad	
14	Clean brick hardcore used and placed at correct thickness and dimensions as target pad	
15	Verticality checked after installation of the basal unit and surrounding aggregates	
16	Photographic record kept of each construction stage	
17	Correct first extension units supplied to site and stored in accordance with manufacturer's guidance	



Drainage Layer - Thickness Trial Pit Record

Site:

Job No :

Project:

Engineer:

Material:

[illegible]

TerraConsult

CQA Inspector:

Site:

CQA Form 28

Job No:

FILTRATION GEOTEXTILE DELIVERY RECORD

[illegible]