WITHYHEDGE LANDFILL
PHASE 2, CELL 10

Construction Quality Assurance Plan for Basal Lining

Report Number 2511r2v1d0225

Commissioned by

Resources Management UK Ltd
Withyhedge Landfill & MRF
Rudbaxton
Haverfordwest
SA62 4DB

Prepared by

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February 2025

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1 INTRODUCTION

1.1 In order to allow continuation of landfill operations at Withyhedge Landfill Site, Cell 10 is to be prepared to accept waste.

1.2 The Designer and Engineer for the Works appointed by Resources Management UK Ltd is Ewan Thomas, Geotechnology Limited, Ty Coed, Cefn-yr-Allt, Aberdulais, Neath. The Engineer has delegated day to day supervision and quality responsibility to the CQA Engineer.

1.3 The preparation and lining of the cells will comprise:-

- Excavation of site won material within the cell footprint and elsewhere within the Permit Area.
- Earthworks comprising filling and compaction to form the cell design formation
- Deposition of unsuitable material (site won earthworks materials) into the agreed area or to facilitate site infrastructure as directed by the Engineer.
- Construction of engineered sidewalls and base comprising a layer of engineered mineral liner to specified thickness, Geosynthetic Clay Liner (GCL), Flexible Membrane Liner (FML) and a protective fabric layer to the base and sidewalls.
- Construction of leachate sump and monitoring points.
- Construction of cell leachate drainage, including pipework and an aggregate drainage blanket.

2 CONSTRUCTION QUALITY ASSURANCE (CQA)

2.1 Introduction

2.1.1 This CQA method statement describes how the construction of Cell 10 is to be monitored to verify that it has been built in accordance with the Specification.

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 Engineer has devised this CQA method statement in accordance with current guidance so that it is practical, achievable and ensures the highest standards of environmental protection. The Engineer shall provide a qualified CQA Engineer to site to provide full time supervision and quality assurance of the lining works in accordance with this CQA method statement to confirm compliance with the Specification. The Engineer will also produce and submit a validation report upon completion of each phase of the works.

2.1.4 Staff from Geotechnology 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 personnel anticipated to be involved in the works are listed below, but suitable substitution using personnel with equivalent experience may be made due to unavailability:

The Engineer – Ewan Thomas
CQA Engineers – Ewan Thomas, Arwel Jones, Ben Rees, Keir Thomas, Jack Morgan

2.1.5 The main duties of the CQA Engineer shall be:

1. to supervise the construction of the cell liner to confirm 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 CVs of the proposed Geotechnology CQA engineers are included in Appendix A.

2.1.7 Only staff approved by NRW shall form the CQA Team. Proposed changes to the CQA staff shall be notified to the NRW along with CV's and will not attend site until approved.

2.1.8 The CQA Engineer shall refer any design changes required to the Engineer who will amend any Specification or Drawing requirements after first consulting with NRW on the change required. Only when NRW provides approval will any changes to the Design or Specification be made.

2.1.9 The CQA Engineer shall inform NRW prior to commencement of work on site.

2.1.10 The CQA Engineer shall review the Contractor's method statements for each element of the works and provide acceptance to the Contractor following any revisions that may be necessary.

2.1.11 The Geotechnology CQA Engineer shall report daily to the Engineer 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 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
i. samples taken
j. repairs
k. CQA installation checklist
l. site meetings
m. progress photographs (which shall record all major construction elements of the project)

2.1.13 The daily records will form part of the certification of the preparatory and engineering works and shall be made available to NRW when required.

2.1.14 Staff from 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 NRW updated as to the progress of work on site. Wherever possible, the CQA Engineer shall liaise with all visiting NRW staff.

2.1.15 The CQA Engineer shall prepare a report every week highlighting the following:-

i. Work carried out during the week
ii. Testing carried out during the week
iii. Sources used during the week
iv. Problems encountered/actions taken
v. Programme for the following week

2.1.16 The report shall be prepared as soon as possible following the end of the week for discussion with the construction team and client.

2.1.17 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 NRW.

2.1.18 All non-compliances shall be reported in the validation report along with the corrective actions.

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 day's 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

2.3.1 In the event of CQA Engineer staff changes or unforeseen absence a replacement CQA Engineer will attend site before construction works can resume.

2.4 Temporary Works – Surface Water Management

2.4.1 A temporary surface water management plan shall be developed between the client, contractor and Engineer prior to the start of the cell construction project.

3 DESCRIPTION OF THE WORKS

3.1 The works

3.1.1 The works comprise the construction of Cell 10 including the installation of a cell lining system and leachate drainage system as specified in Appendix B.

3.1.2 The works are to be carried out in accordance with the drawings listed below. No details shall be changed by the Engineer without the written permission of NRW. The Engineer shall review any proposed changes and if they involve a departure from the Specification shall require confirmation from NRW that the changes have been approved.

2511/1 Location of Cell 10
2511/2 Footprint of Cells 6-10
2511/3 Cell 10 Formation Levels
2511/4 Cell 10 Groundwater Levels
2511/5 Top of Compacted Clay AEGB
2511/6 Example Geosynthetic Panel Layout
2511/7 Leachate Drainage Arrangements
2511/8 Construction Detail Section Locations
2511/9 Sideslope Details
2511/10 Construction Details

4 FORMATION LAYER AND GENERAL BACKFILL

4.1 The CQA Engineer shall:

i. confirm that the proposed site won materials have been classified in accordance with Schedule 600 of the MCD Specification for Highway Works and that the contractor has selected an appropriate combination of lift thickness and number of passes for the compactor plant used on site;

ii. confirm by unannounced monitoring that the correct lift thickness and number of passes are achieved to build the fill layer to formation levels;

iii. confirm that all earthworks material deemed unsuitable in accordance with the Specification is removed to an area agreed with the Site Manager and not used in the works;

iv. confirm that the existing intercell bunds are prepared without damaging the edge of the existing liner in Cells 6 & 9;

v. confirm that only suitable materials are used where required as engineered fill;

vi. confirm all areas of non-compliance are remediated in accordance with the Specification;

vii. 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;

viii. ensure that the topographic surveys are carried out on completion of the prepared formation in accordance with the CQA survey requirements detailed within the Specification to confirm that the requisite levels have been attained;

ix. confirm that the sump for the leachate extraction chamber is excavated in accordance with the Specification and that the formation surfaces are picked up by detailed topographic survey;

4.2 The CQA Engineer shall confirm that all elements are documented and are included in the CQA Validation Report.

5 ENGINEERED MINERAL LINER (EML)

5.1 The CQA Engineer shall:

i. review the results of the laboratory testing carried out by the Engineer on the proposed source materials to confirm compliance with the Specification;

ii. confirm large scale shear box testing has been completed and the results meet the requirements of the specification.

iii. confirm that the material proposed to form the liner is tested in accordance with the CQA Programme for source testing provided in LFE4 and ensure that the results of the source testing are used to confirm that the proposed source material is acceptable.

iv. submit the source test results to NRW for acceptance and issue a source acceptance notification to the Contractor prior to its use on site;

v. confirm that only suitable materials are used where required as engineered mineral liner;

vi. confirm that a trial liner is undertaken for each source used, in accordance with the requirements set out in the Specification on the cell base and against the sidewalls;

vii. ensure that a trial liner is carried out if the plant used for the compaction of the engineered liner is changed at any time during the Works;

viii. provide verbal approval to the Contractor that the surface on which the compacted clay liner 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

ix. monitor the placement and compaction of the liner 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;

x. maintain an on-going record of the quantity of liner and/or layer/liner area completed at any one time in order to check that the frequency of CQA compliance tests as specified in LFE4 is being achieved;

xi. ensure sampling and testing is carried out at the frequency required by the Specification;

xii. confirm all areas of non-compliance are remediated in accordance with the Specification;

xiii. provide confirmation that the final surface of the liner has been prepared in accordance with the requirements of the Specification;

xiv. ensure that the topographic survey is carried out on the prepared finished surface and following completion of the liner confirm that the requisite thicknesses, levels and gradients have been attained.

xv. Confirm that the sump for the leachate extraction chamber is excavated and lined in accordance with the Specification.

xvi. confirm that the mineral liner beneath the leachate extraction chamber and monitoring points are constructed using materials and products compliant with the Specification.

6 GEOSYNTHETIC CLAY LINER (GCL)

6.1 The CQA Engineer shall:

i. confirm that the GCL 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, panel layout, field quality control forms, ensuring that the information is in accordance with the Specification;

iii. 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 NRW for agreement;

iv. assess the MQC data sheets to confirm that the material supplied meets the requirements of the Specification, prior to installation;

v. confirm that each roll of GCL delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification;

vi. take samples of the GCL and arrange for conformance testing in accordance with the Specification;

vii. assess the conformance test results and confirm whether the requirements of the Specification have been met;

viii. confirm 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;

ix. confirm that the GCL is deployed on a subgrade prepared in accordance with the Specification using agreed, acceptable methods and record the methods used;

x. confirm that the GCL is installed in the same configuration and the same way up as used for the interface testing.

xi. confirm that the GCL deployed meets the requirements of the Specification for condition, panel layout, seam overlap and accessory bentonite seaming;

xii. confirm 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. confirm that prior to the deployment of any further GCL any excessively hydrated GCL as indicated by a variation in colour, or thickness compared with the surrounding material is either covered with new material or removed and replaced;

xiv. confirm that the leading edge of the GCL already covered with the geomembrane is inspected for approval prior to deployment of the adjacent GCL panel;

xv. instruct appropriate repair work in accordance with the Specification and confirm that the repair work is completed, tested and is compliant, in accordance with the Specification;

xvi. confirm that the geomembrane liner is installed over the surface of approved GCL as soon as possible after the GCL is laid and in any event prior to rainfall and or the end of the working day;

xvii. confirm that the geomembrane liner is fully sealed and welded progressively prior to forecast rainfall during the installation process to prevent water ingress at geomembrane repair patches and or seams;

xviii. confirm that the panels are surveyed 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;

xix. confirm that the contractor places leachate drainage stone spine roads progressively during liner installation programme onto the liner system at a minimum 1m depth to provide initial loading and reduce the risk of premature hydration and or separation of GCL seams and or separation of the GCL from its subgrade. The programme for this is to be agreed with the contractor at the pre-start meeting.

6.2 The CQA Engineer shall confirm that all elements are documented 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. confirm that the FML proposed to be supplied meets the requirements of the Specification;

ii. confirm 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 NRW for agreement;

v. confirm 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. confirm that each roll of FML delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification;

viii. confirm 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.

x. assess the conformance test results and confirm whether the requirements of the Specification have been met;

xi. confirm that the FML is deployed on a compliant gcl surface and that the FML is weighted down (temporary surcharge) in accordance with the agreed Contractor's method statement and/or the Specification;

xii. confirm 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. confirm that the FML deployed meets the requirements of the Specification for condition, thickness, panel layout and seam overlap;

xiv. confirm that all pre-weld tests and trials are carried out and are compliant with the Specification;

xv. confirm that seaming takes place only after compliant pre-weld trials, in compliant weather conditions and on compliant sheet and seam conditions;

xvi. confirm that all seams and welds undergo the appropriate non-destructive and destructive testing in accordance with the Specification and that the results are compliant; instruct appropriate repair work in accordance with the Specification and confirm that the repair work is completed, tested and is compliant, in accordance with the Specification;

xvii. ensure that a topographic survey is undertaken 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 confirm that all elements are documented according to the CQA Programme attached at Appendix B and that the records and test results are presented in the validation report.

8 PROTECTIVE GEOTEXTILE

8.1 The CQA Engineer shall:

i. confirm, 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. confirm 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 NRW for agreement;

v. confirm 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. confirm that each roll of geotextile delivered to site is unloaded, handled and stored in accordance with the requirements of the Specification;

viii. take samples of the geotextile and arrange for conformance testing in accordance with the Specification.

ix. assess the conformance test results and confirm whether the requirements of the Specification have been met;

x. confirm 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. confirm that the geotextile is deployed in accordance with the Specification using agreed, acceptable methods and record the methods used;

xii. confirm that the geotextile deployed meets the requirements of the Specification for condition, panel layout and seam overlap;

xiii. confirm that deployment and seaming takes place only in compliant weather and seam conditions;

xiv. instruct appropriate repair work in accordance with the Specification and confirm that the repair work is completed and is compliant, in accordance with the Specification;

xv. confirm that a topographic survey is undertaken 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, including any repairs, prior to granting approval for the placement of the overlying leachate drainage layer;

8.2 The CQA Engineer shall confirm that all elements are documented and that the records and test results are presented in the validation report.

9 LEACHATE COLLECTION & CONTROL SYSTEM

9.1 Leachate Drainage Aggregate

9.1.1 The CQA Engineer shall:

xvii. 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;

xviii. assess the quality control test results provided by the Contractor to confirm that the proposed aggregates meet the requirements of the Specification and provide approval prior to delivery to site;

xix. collect representative samples of the aggregates and arrange for compliance testing in accordance with the Specification;

xx. assess the results of the compliance testing and confirm whether the requirements of the Specification have been met;

xxi. continuously monitor aggregate placement operations ensuring that the characteristics of the material do not change, and that the lining system is not compromised;

xxii. confirm 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;

xxiii. confirm that the contractor places leachate drainage stone spine roads progressively during liner installation programme onto the liner system at a minimum 1m depth to provide initial loading and reduce the risk of premature hydration and or separation of GCL seams and or separation of the GCL from its subgrade. The programme for this is to be agreed with the contractor at the pre-start meeting.

xxiv. confirm that aggregate is placed at levels as shown on the Drawings at a thickness equal to or greater than the minimum allowable thickness by either topographic survey or by careful probing / mini trial pits at regular intervals (25m) prior to the survey;

xxv. confirm 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.

9.2 Leachate Drainage Pipework

9.2.1 The CQA Engineer shall:

xxvi. confirm that the Contractor provides the product details with supporting calculations on the products proposed for each diameter of pipe to be used to form the leachate drainage pipework in accordance with the requirements of the Specification;

xxvii. assess the product details and supporting calculations to confirm compliance with the requirements of the Specification for each diameter of pipe to be used;

xxviii. confirm that all pipework associated with the leachate collection system is delivered, stored and handled in accordance with the manufacturer's recommendations and or Specification;

xxix. confirm that the pipework is installed at the locations shown on the relevant Drawings;

xxx. confirm that the pipework joints are constructed in accordance with the Specification;

xxxi. confirm that where butt-welding techniques are applied, 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 confirm that the welding records and information are provided in accordance with the Specification;

xxxii. confirm 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;

xxxiii. the CQA Engineer shall confirm that the welding records and information are provided in accordance with the Specification. No electrofusion couplers are to be used on slotted or perforated pipework.

xxxiv. confirm that the pipe installation, pipe bedding and gravel haunch over the pipework is in accordance with the Specification;

xxxv. confirm that the Contractor surveys the level of the top of the pipework and the end points of each drainage pipe.

9.3 Leachate Chamber, Monitoring Points & Target Pads

9.3.1 The CQA Engineer shall:

xxxvi. 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;

xxxvii. confirm that an 'as built' survey is undertaken showing position, layout and extent and level of the leachate collection chamber, leachate monitoring points and target pads;

xxxviii. The CQA Engineer shall confirm that all elements are documented and that the records are presented in the validation report.

10 ELECTRICAL RESISTIVITY LEAK TESTING SURVEY (ERLTS)

10.1 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. confirm 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 confirm that the survey is carried out in accordance with the accepted method statement and the Specification;

v. confirm that any damage in the FML identified during the ERLTS survey is repaired and tested according to the requirements of the Specification;

vi. confirm that an electrical resistivity leak 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.

10.2 The CQA Engineer shall confirm that all elements are documented and that the records are presented in the validation report.

11 CONSTRUCTION QUALITY ASSURANCE VALIDATION REPORT

11.1 Following completion of the works, Geotechnology will report fully on the quality control testing and observations undertaken during construction. The report shall be submitted to Natural Resources Wales within 6 weeks of the works completion date.

11.2 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:

1) Description of the works;
2) Daily Records and all CQA forms, tables, spreadsheets or records used to monitor and validate compliance;
3) Manufacturer's and Contractor's documentation;
4) Test Reports, both laboratory and field;
5) Photographic Records;
6) As-built Drawings;

In addition to the above items the Engineer shall ensure that the following are included in the report:

1) Description of non-conformances and the subsequent remediation (including photographs of all repairs made to geomembrane & GCL);
2) 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).
3) An Isopachyte of the clay liner thickness and leachate drainage layer thickness
4) The as-built drawings will include as a minimum:
    - title of project
    - name of contract
    - element of works reported
    - drawing version number with details of revision history; scale (Scale at size to be printed, e.g. 1:500 at A1)
    - details of the survey grid with grid intersections
    - locations of control stations/levels
    - benchmarks etc. (permanent and temporary)
    - north arrow
    - where possible there will be a distinction between surveys done on different times and dates

WITHYHEDGE LANDFILL
PHASE 2, CELL 10

Construction Quality Assurance Plan for Basal Lining

Report Number 2511r2v1d0225

Appendix 1 Staff CVs

ARWEL JONES

PROFESSIONAL PROFILE

POSITION Director and Geotechnical Specialist, Geotechnology Ltd., Aberdulais, Neath

Date of Birth 12 May 1964

Arwel is a director of Geotechnology Ltd and is a geotechnical specialist with 32 years geotechnical consultancy and contracting experience. He is actively involved in a range range of geotechnical work which includes landfill geotechnics. Arwel has a broad experience of working within a geotechnical consultancy and has a wealth of experience in the management of geotechnical field activities. Arwel liaises with a diverse client base ranging from private individuals to multinational companies. He has worked in many areas of the United Kingdom and in overseas projects involving various geotechnical projects in both technical and project management roles with Geotechnology and Golder Associates.

Arwel has worked on numerous large scale multinational projects, including a major road construction project for a British construction company on the Oman / Yemeni border. The work entailed significant slope stabilisation in the form of multi-strand rock anchors, high tensile steel mechanical and resin bolting, shotcrete application and meshing.

South Wales has a legacy of historical coal mining, which has resulted in subsidence and stability issues. Arwel has been involved in a significant number of coal mining investigation and remediation projects comprising undertaking the initial coal mining risk assessment through to remediation of mine workings via pressurised grout stabilisation. Such work has often been part of a construction project and Arwel has completed a large number of site investigations to provide suitable foundation design recommendations for individual clients, large housebuilders and multinational industrial companies.

The construction and operation of landfills continues in many parts of the country and Arwel has significant experience in the investigation for design and provision of construction quality assurance to their completion. Arwel has been involved in the design and placement of a number of landfill lining projects where the use of bentonite enriched sands were used due to the lack of natural lining materials. Arwel also has significant experience in the use, testing and placement of geo-synthetic materials in landfill construction. Arwel has reviewed technical reports for the Environment Agency (and its successor in Wales, Natural Resources Wales) on landfill geotechnical matters for the last 18 years. Arwel is also a Fellow of the Geological Society of London and is active in its Engineering Group.

Arwel undertakes technical work for the practice which involves national government, local government, government agencies, multinational and national, industrial and commercial clients, national housebuilders and small developers. He has contact with technical staff from other companies and organisations when work is being implemented on specific projects.

BEN REES

PROFESSIONAL PROFILE

POSITION Director and Environmental Geochemist, Geotechnology Ltd., Aberdulais, Neath

Date of Birth 24 August 1975

Ben is a director of Geotechnology Ltd and is an Environmental Geochemist with 25 years consultancy experience. Since joining Geotechnology in 2008, Ben has been actively involved with a broad range of project work utilising his geochemical knowledge and wider geoscientific experience. In the UK, this has involved a wide selection of projects related to Phase I and II land quality assessments, environmental and human health risk assessments, design and implementation of environmental monitoring programmes, permit applications for a range of waste sectors, waste classification and landfill construction design and CQA supervision.

Specifically related to landfill, Ben has provided geochemical and waste classification input to Hydrogeological Risk Assessments (HRAs) and Gas Risk Assessments (GRA) for several active non-hazardous and hazardous landfills. In Wales, Ben continues to provide direct input to assessments at Palleg landfill in the Swansea Valley, Nantycaws in Carmarthenshire, Tir John in Swansea, Withyhedge in West Wales and Morfa Landfills in Port Talbot. In England, Ben has also completed assessments of several non-hazardous and inert facilities including sites where piggybacking has been proposed and unlined active gassing sites close to residential properties requiring detailed gas risk evaluation.

Ben has also contributed to the development of capping schemes and the development of long-term aftercare monitoring programmes at several closed landfill sites including East Waste Management Site and Southside Queensway at Llanwern Steelworks, Nantycaws and Wernddu in Carmarthenshire, Morfa Closed Landfill at Port Talbot Steelworks and Cwrt y Plyffin in Powys. Alongside colleague Ewan, Ben has also investigated several illegal waste deposits on behalf of Natural Resources Wales (NRW), providing Expert Witness services related to waste classification and environmental risk at Crown Court. Many of thee assessments have utilised specialist computer software programmes Landsim and Gassim and with colleagues Ewan and Keir, Ben was recently involved with training NRW personnel in the use of these models and the fundamental principles of landfill design.

Ben's involvement with landfill engineering also extends to the CQA supervision of new landfill cells and landfill capping at each of the sites mentioned above. This includes approving sub-grade ahead of geomembrane placement, monitoring geomembrane placement and jointing, monitoring the placement of drainage and gas collection geosynthetics and capping with restoration soils. Each job has required detailed record keeping and the compilation of CQA Verification reports.

EWAN THOMAS

PROFESSIONAL PROFILE

POSITION Director and Principal Geotechnical Specialist, Geotechnology Ltd., Aberdulais, Neath

Date of Birth 9 February 1963

Ewan is a director of Geotechnology Ltd and is a geotechnical specialist with 35 years geotechnical consultancy and contracting experience. He is interested in, and actively involved in, a broad range of geotechnical work as well as his niche areas of expertise in landfill geotechnics. He has worked throughout the world undertaking various geotechnical projects in both technical and managerial roles with Geotechnology and Golder Associates.

Ewan has co-authored a number of scientific papers published in per reviewed journals and has delivered a number of presentations at professional and academic conferences. He is a Senior Lecturer in Geotechnical Engineering at Cardiff University where he is responsible for the delivery of vocational geotechnical training to postgraduates on the taught masters programme. Ewan is retained by the Civil Engineering department as an external geotechnical advisor and has also acted as external advisor to the academic syllabus team at Swansea University's Civil Engineering Department.

Ewan has been retained by the Environment Agency (and its successor in Wales, Natural Resources Wales) to advise on landfill geotechnical matters for the last 21 years. As part of this work Ewan regularly works with Compliance and Environmental Crime teams in preparing technical submission for Magistrate and Crown Court proceedings. He regularly acts as an expert witness in criminal trials and as an advisor in compliance disputes at Magistrates Court on matters related to geotechnical engineering, permit compliance and waste classification. Ewan has just authored its internal Guidance for waste quantification.

Ewan is a member of the Wales Ground Engineering Group (GEG) of the Institution of Civil Engineers. Ewan was its Chairman in 1998-2000. Ewan is also a Fellow of the Geological Society of London and is active in its Engineering Group.

Ewan has technical responsibility for the professional output of the practice. He liaises with clients that include national government, local government, government agencies, multinational and national industrial and commercial clients, national housebuilders and small developers. He has day to day contact with directors and senior staff within the client organisations and often prepares briefing notes for upper and middle management.

Ewans landfill experience includes the design and specification of Landfill Directive compliant Hazardous, Non-Hazardous and Inert Landfill and is called upon regularly by Regulators to assist with the investigation of engineering problems at regulated sites. He has designed complex steep wall lining systems using finite element modelling and has been used by the EA to review similar submissions. He has designed capping systems on hot landfills (83°C), specified CQA procedures on the Sellafield low level nuclear waste repository and has advised Tata and its successors on Numerous landfill developments across its portfolio as well as a number of other steelworks sites across the UK.

KEIR JAMES THOMAS BSc. MSc. FGS.

PROFESSIONAL PROFILE

POSITION Geotechnical Engineer

DATE OF BIRTH 28 May 1988

Keir Thomas is a Geotechnical Engineer with 11 years industrial experience. He has a B.Sc. (Hons) in Geology and MSc. (Distinction) in Applied Environmental Geology from Cardiff University. He retains close links to the university and regularly assists in vocational field training for the MSc students.

During his time in industry, he has been actively involved in a wide variety of geotechnical and geo-environmental work. In his role as a Geotechnical Engineer, Keir is regularly involved in the planning, organisation, and supervision of site work; liaising with both clients and suppliers. He is highly experienced in site investigation, geotechnical monitoring, topographic surveying, geophysical surveying, landfill design, earthworks design and construction supervision.

Keir's landfill experience includes the design and specification of new landfill cells and capping schemes for both hazardous and non-hazardous landfills. He has also aided in the design of restoration schemes for historic industrial slurry lagoons. Keir has extensive experience in the supervision and CQA validation of the construction phase of these schemes. Post construction, he has also managed the ongoing environmental and geotechnical monitoring of both active and closed landfill sites.

Practical site work has given Keir expertise in the use of numerous pieces of field equipment; ranging from in-situ soil testing equipment to high end topographic and geophysical survey instrumentation. He is also experienced in the application and supervision of most conventional intrusive ground investigation techniques.

Keir has comprehensive experience and training in the use of several specialist software packages for applications including slope stability monitoring and analysis, digital terrain modelling, 3D modelling, volumetrics, earthworks design, and settlement analysis.

Keir is a qualified drone pilot with specialisation in the use of photogrammetry drones to carry out large scale topographic surveys, and volumetric assessments. He has undertaken topographic drone surveys for use in several sectors including earthworks, construction, the steel industry, renewable energy, waste management and regulation. He regularly uses drone surveys to complete the annual topographic survey and volume assessment at a number of local landfills.

Keir was elected a Fellow of the Geological Society of London in January 2010. He has an active involvement in the Southern Wales Regional Group of the society; serving on the committee since 2014, holding the position of Secretary from 2017-2019 and Chairperson from 2019 to present. He has also contributed on field trips organised by the Engineering Group of the Geological Society and given a talk to the Ground Engineering Group of the Institute of Civil Engineers. He won the Southern Wales regional heat of the Early Career Geologist Award in 2018.

WITHYHEDGE LANDFILL
PHASE 2, CELL 10

Construction Quality Assurance Plan for Basal Lining

Report Number 2511r2v1d0225

Appendix 2 Design and Engineering Specification

WITHYHEDGE LANDFILL
PHASE 2, CELL 10

Basal Lining Engineering Specification

Report Number 2511r1v1d0225

Commissioned by
Resources Management UK Ltd
Withyhedge Landfill & MRF
Rudbaxton
Haverfordwest
SA62 4DB

Prepared by
Geotechnology Ltd
Ty Coed
Cefn-yr-Allt
Aberdulais
SA10 8HE

February 2025

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1 INTRODUCTION

1.1 General Detail

1.1.1 In order to allow continuation of landfill operations at Withyhedge Landfill Site, Phase 2 Cell 10 is to be prepared to accept waste.

1.1.2 The preparation and lining of the cell will comprise:-

- Excavation of in-situ bedrock, clay soils and other site won material within the cell footprint and elsewhere within the Permit Area.
- Earthworks comprising filling and compaction to form the cell design formation to the accuracy specified.
- Deposition of unsuitable earthworks material into the agreed area or to facilitate site infrastructure as directed by the Engineer.
- Construction of engineered sidewalls and base comprising a layer of engineered mineral liner to specified thickness, Geosynthetic Clay Liner (GCL), Flexible Membrane Liner (FML) and a protective fabric layer to the base and sidewalls where these are formed over in-situ natural ground.
- Construction of leachate sump and monitoring points.
- Construction of cell leachate drainage, including pipework on the cell floor and an aggregate drainage blanket across the cell floor and up the sideslopes to a height of 4m
- Construction of a geocomposite design layer above the aggregate blanket transmit any perched leachate into the blanket.

1.2 The Engineer

1.2.1 The Designer and Engineer for the Works as appointed by Resources Management UK Ltd is Ewan Thomas, Geotechnology Limited, Ty Coed, Cefn-yr-Allt, Aberdulais, Neath. The Engineer has delegated day to day supervision and quality responsibility to the CQA Engineer.

1.3 Background to Cell 10 Construction

1.3.1 Resource Management UK Ltd operates the Withyhedge Landfill Site at Rudbaxton, Haverfordwest. As part of its basal lining works it submitted proposals in early 2024 for the construction of Cell 9, these were accepted by NRW. Cell 9 is divided into 3 parts and sequential construction of all three was undertaken throughout 2024. Cell 9 has been approved by NRW, and the deposition of waste commenced in January 2025.

1.3.2 An analysis of waste inputs against remaining capacity has shown that Cell 9 has insufficient capacity to last until Autumn 2026. To avoid construction during inclement weather the next cell therefore has to be constructed in this summer's lining season. Accordingly, Geotechnology has been asked to design the next cell and to supervise its construction before the Autumn of 2025.

1.4 Cell 10 Location

1.4.1 The location of Cell 10 within the Withyhedge landfill is shown on Drawing 2511/1 and on Figure 1-1. It lies to the west of the currently operational Cell 9 and to the south of cells 5 & 6. The cell will be positioned partly within the bedrock excavation made as a source of fill material for previous construction schemes. Drawing 2511/2 shows the proposed formation levels for Cell 10.

Fig 1-1 Cell 10 Location

1.5 Cell 10 Formation

1.5.1 Cell 10 will have its base constructed at the edge of the existing void created by previous excavation into the natural shale bedrock. Basal levels will be modified to ensure the required standoff between the liner and the groundwater is established. Drawing 2511/4 shows the separation between the top of formation and the groundwater when the groundwater is at its seasonal maximum (January). Excavation work in the southern section of the basal tray has identified a natural clay deposit which will be utilized for the geological barrier, the northern section of the cell that abuts the Cell 6 bund will require the placement of fill material to meet design levels. The western bund will be created within the void by filling and will form a separation between Cell 10 and future Cells, this bund lies inside but follows the alignment of the existing hedge line.

1.6 Basal Engineering

1.6.1 Over its entire basal footprint, Cell 10 will be constructed precisely as previous cells, with an Artificially Established Geological Barrier (AEGB) comprising low permeability clays overlain with a Geosynthetic Clay Liner (GCL) and a high density polyethylene flexible membrane artificial sealing liner (ASL). The basal tray of the Cell is separated into two sub-cells, each designed to drain leachate to its own sump, to facilitate this the ASL is covered with a layer of drainage aggregate containing perforated pipes. To protect the hdpe ASL from damage by the overlying drainage blanket the ASL is covered with a thick protective needle punched fabric.

1.6.2 Wherever possible, construction materials will be obtained from the same sources as they have for previous cells. However, the site won clay source is now so depleted that the AEGB cannot be formed from site won Clay. Accordingly, clay will be imported from

an approved source, subject to source approval testing. The GCL, hdpe ASL and protective fabric will all be sourced from the same manufacturer through the same suppliers as will the drainage stone and pipework products.

1.6.3 A source evaluation report for the AEGB is required prior to acceptance for use at the site. This report will be reviewed by the designer to confirm acceptability and forwarded to NRW for its review and acceptance. The acceptance of the source evaluation report will apply to that single source only. A compaction trial is still required prior to commencement of the lining works.

1.6.4 This document is an evolution of the Cells 6-9 construction details, with a number of amendments. Rather than draft a completely new Specification and CQA Plan, the existing approved documents have been used and adjusted where necessary to describe these refined proposals. The principal differences between the approved documents and these documents are:

Revision to Approved Footprint
Cell 10 will be constructed at the location shown on Drawing 2511/1.

Sub-division of Cell into 2 Parts
Cell 10 is a large cell designed to provide significant ongoing capacity. In order to expedite progressive capping and to reduce leachate yields, Cell 10 will be divided into 2 sub-cells, with sub-cell A to the north (first to be completed and filled), and sub-cell B to the south. The cell will be divided with a 1.5m high internal bund. Leachate will be collected from Cell 10 at two sumps, each draining a separate leachate collection system in each of the cells.

Revision to Unsaturated Zone Thickness
The approved Cell 6-9 designs implemented a 1.5m thick unsaturated zone to account for the short duration of the groundwater level monitoring dataset. Several years of data is now available providing a comprehensive dataset that exceeds the Pre-operational Requirement of 12 months data. In order to reduce the volume of material that would need to be imported to build levels up to ensure a 1.5m unsaturated zone, the thickness has been reduced to 1.2m as shown on Drawing 2357/4.

Use of Weathered Shale Capping Layer
The proposals for Cell 10 require up to 4m of fill to be placed to build embankments and to raise the basal tray to the required level as shown in Figure 1-2. The cell will have a low permeability AEGB placed beneath it and wherever available the fill to formation will use weathered shale bedrock.

Leachate Drainage
Leachate will be drained from each sub-cell in Cell 10 by a piped drainage blanket. The blanket will fall from south to the northwest and will be fitted with a pair of spine drains. Leachate will gravitate through spur drains and the spine drains to a leachate sump in the northwest corner of each sub-cell, where a telescopic leachate shaft will be constructed to remove leachate. A pair of spine drains will be provided (redundancy in design) with spur drains at 30m intervals. The spine drains will not flow directly into the sump but will divide some 10m before the sump, with stub pipes connecting the sump to the spine drains. This allows a retro-drilled replacement sump to be drilled in the future at the lowest point of each sub-cell.

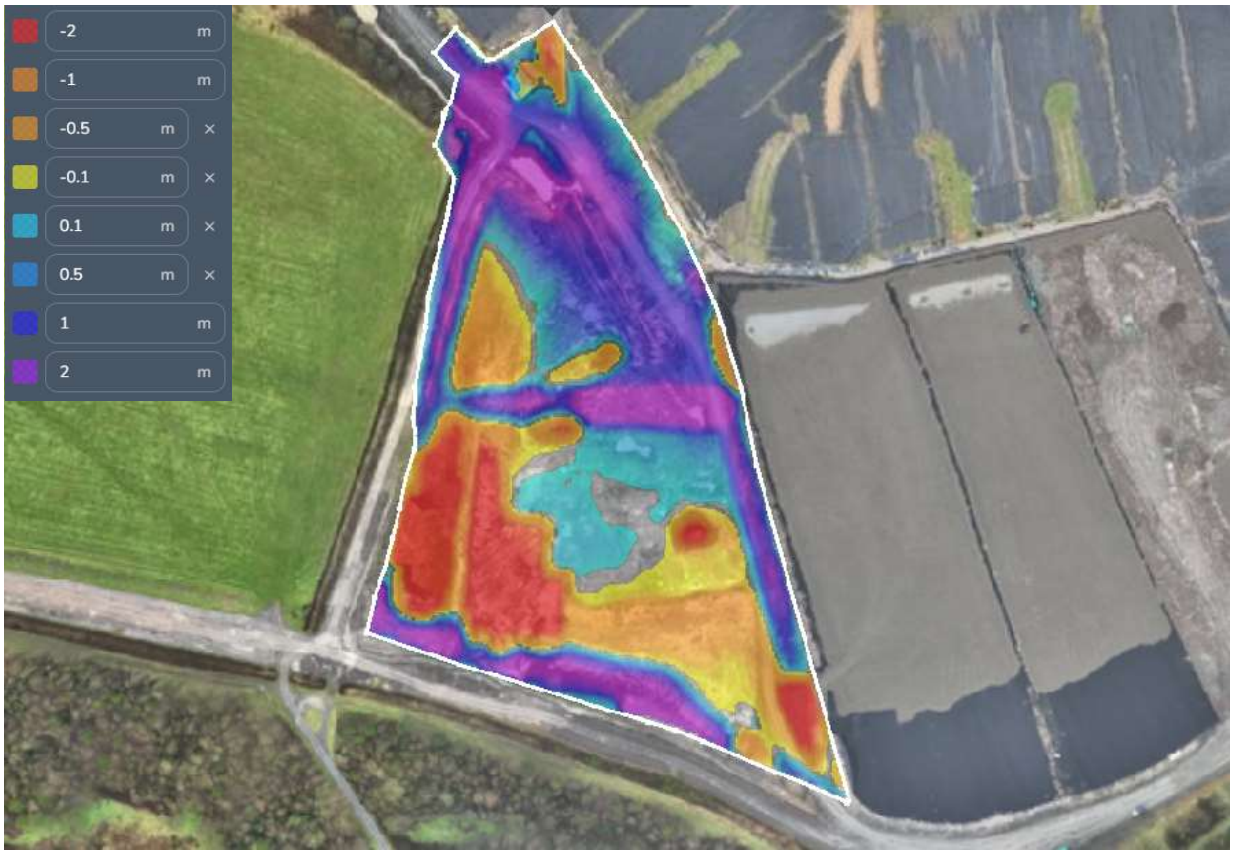


Fig 1-2 Cell 10 Formation Reprofiling

Target Pads and Infrastructure Foundations

All infrastructure that could apply a load to the base of the cell will be positioned above a foundation slab. The slabs will be high grade sulphate resisting reinforced concrete of 200mm thickness and will be cast onto 200mm deep depressions in the lining system. The depressions will be lined as the remainder of the cell but will also have a further layer of HDPE on top of the protective fabric to form a smooth base to the concrete slab. The slab edges will be feathered out to avoid point loading at the slab edge. Target pads will each have a reinforced concrete base and will be positioned beneath a 1m brick marker layer.

Leachate Design on Upper Sideslope

The southern batter of Cell 10b is tall but aggregate will be placed for leachate drainage only across the base of the cell and to a vertical height of 4m above the base (the lower 13m of the batter). Above this, drainage of leachate will be assisted by providing a geocomposite layer laid over the protection fabric during disposal operations.

Phased Construction

The construction of Cell 10 will be undertaken in one continuous operation. Firstly, the formation will be established in advance of the lining works allowing observation of formation for several weeks before lining works commence. Then the AEGB will be progressively installed onto formation commencing at the edge of Cell 9 and progressing westward, firstly in sub-cell A, then repeated for sub-cell B. Once mineral works are complete in sub-cell A the mineral lining plant and personnel will continue in sub-cell B whilst the specialist lining crew will install geosynthetics into sub-cell A.

With progressive construction, sub-cell A will be complete first and it is envisaged that a Validation Report for sub-cell A will be submitted whilst works are ongoing in sub-cell B.

It is anticipated that both Validation Reports will be submitted by late Autumn 2025.

2 GENERAL SPECIFICATION

2.1 Scope of Works

2.1.1 The Works will be completed within a strict Construction Quality Assurance framework as detailed in the Construction Quality Assurance Method statement. The Contractor shall take all necessary measures to enable the Engineer to make a successful submission to Natural Resources Wales. 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:

- Earthworks (cut and fill) to achieve formation level.
- Construction of any temporary works (bunds or embankments) to facilitate surface water management.
- Place engineered clay liner to include basal and sidewall lining and intercell bunds.
- Grade and finish the top surface of the engineered clay liner.
- Provide and install GCL on Engineered Clay Liner.
- Provide and Install FML on GCL
- Provide and install protective geotextile on FML.
- Import and place leachate drainage aggregate on protective geotextile over base and lower sideslopes.
- Install leachate extraction chamber.
- Install leachate monitoring points.
- Install leachate target pad.
- Install leachate drainage pipes with stop end at upgrade end of pipes.
- Grade surface of leachate drainage layer.
- Undertake Geophysical Leak Location Survey and repair any defects found during survey.
- Submit CQA Validation for works for basal tray and lower sideslope.

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

2.2.3 The Contractor should allow for independent check surveys to be made within their works programme.

2.2.4 The Contractor shall ensure they are aware of the programme restraints regarding access to the works areas.

2.2.5 The Contractor is to follow a programme of works that minimises risk of premature hydration of the GCL and or separation of GCL seams and or separation of the GCL from its subgrade. The programme for this is to be agreed with the contractor at the pre-start meeting.

2.2.6 The Contractor shall develop a programme for approval which allows for the progressive deployment and installation of liner layers to achieve 2.2.5.

2.3 List of Contract Drawings

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

Table 2-1 List of Drawings

2511/1	Location of Cell 10
2511/2	Footprint of Cells 6-10
2511/3	Cell 10 Formation Levels
2511/4	Cell 10 Groundwater Levels
2511/5	Top of Compacted Clay AEGB
2511/6	Example Geosynthetic Panel Layout
2511/7	Leachate Drainage Arrangements
2511/8	Construction Detail Section Locations
2511/9	Sideslope Details
2511/10	Construction Details

2.3.2 If deemed necessary, the Engineer shall issue extra drawings to clarify any part of the Works. In the event of a drawing revision, the Contractor shall forward written confirmation notifying the Engineer that his site staff are working to the latest revision. In the event that the Drawings, Bill of Quantities and/or Specification conflict then the Contractor must notify the Engineer immediately in writing requesting clarification on how to proceed. Upon receipt of such a request the Engineer shall instruct the Contractor within 48 hours as to how to proceed, with the Contractor acknowledging said instruction in writing within 7 days.

2.4 Survey Management and Control

2.4.1 The Contractor shall be responsible for ensuring that the Works are completed accurately to the Drawings provided using a combination of conventional dgps topographic survey and gps machine control technology. The CQA Engineer will undertake surveys to confirm that the Works have been installed to the Specification.

2.4.2 The Engineer reserves the right to carry out any surveys he sees fit to check the accuracy of the Contractor's work.

2.4.3 The Contractor shall state the gps machine control equipment he plans to use and shall state the tolerances to which the system works.

2.4.4 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.

2.4.5 All surveys shall be related to the National Grid.

2.4.6 The Engineer shall provide to the Contractor on Site survey control information and digital surface models of:

- Existing Ground Surface
- Top of Formation
- Top of Engineered Clay Liner
- Top of Drainage Blanket

2.4.7 Permanent Ground Markers shall be established 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.

2.4.8 The Contractor shall ensure that his operations do not interfere with, or damage, the Permanent Ground Markers.

2.4.9 The CQA Engineer shall keep updated schedules and drawings of all Permanent Ground Markers related to the Ordnance Survey National Grid used in setting out.

2.4.10 The following surveys shall be required and will be undertaken by the CQA Engineer before acceptance of the successive layer:

	Location	Frequency	Timescale	Format
1	Topographical survey prior to earthworks	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 or 3D topographic model on Propeller system
2	Formation immediately prior to placement of Engineered Liner	Points on a 10 metre square grid plus all valleys, ridge lines and changes in gradient.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file or 3D topographic model on Propeller system
3	Bunds and side slopes immediately prior to placement of Engineered Liner	Points on a 5 metre square grid plus all valleys, ridge lines and changes in gradient. Points to be used to draw section lines at 5m chainage.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file or 3D topographic model on Propeller system
4	Leachate Extraction Chamber and Monitoring Chamber formation	All plan points including set- out corners of concrete 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
5	Leachate Target Pad formation	All plan points including set- out corners of concrete 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
6	Base of cell - Top of Engineered Liner after compaction has taken place	Same points on a 10 metre square grid as used in survey 2 above plus all valleys, ridge lines and changes in gradient.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file 3 dimensional .dwg file or 3D topographic model on Propeller system

7	Cell bunds and side slopes - Top of Engineered Liner after compaction has taken place	Same points on a 5 metre square grid as used in 3 above plus all valleys, ridge lines and changes in gradient. Points to be used to draw section lines at 5m chainage for depth measurement.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file or 3D topographic model on Propeller system
8	Leachate collection point and monitoring points - Top of Engineered Liner after compaction has taken place	All plan points including corners of concrete pads plus all points as necessary to accurately represent the installation. Survey is to include centre point at top of slab.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file
9	Base of Cell - Top of Drainage Stone Layer	Same points on a 5 metre square grid as used in 2 above and every 10 metres along crest of haunch to drainage stone over drainage pipe lines.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file or 3D topographic model on Propeller system
10	Cell bunds and side slopes- Top of Drainage Stone Layer	Same points on a 5 metre square grid as used in 3 above plus all valleys, ridge lines and changes in gradient. Points to be used to draw section lines at 5m chainage for depth measurement.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg file or 3D topographic model on Propeller system3 dimensional .dwg file or 3D topographic model on Propeller system
11	Locations of Engineered Clay Sample Points	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
12	As built layout surveys for Protective Geotextile, FML and GCL	To be agreed with the Engineer on Site but to include material extent, all panel edges, patch repairs, anchor trenches, changes in slope gradient.	Results shall be given to the Engineer within 48 hours of the survey taking place	3 dimensional .dwg
13	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
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
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 and 3D topographic model on Propeller system

2.4.11 The Contractor shall note that no progress shall be allowed on subsequent lining elements until proof is received that the total thickness of the layer being considered is approved.

2.4.12 The CQA Engineer shall undertake the surveying of the cell construction utilising a Topcon rtk dGPS system operating from a fixed local base station or a Network correction. In the event that a network correction is being used the survey shall be immediately preceded by a survey of the control stations and a further control station observation shall be made at the end of the survey.

2.5 Liner Interface Testing (Large scale Shear Box)

2.5.1 The CQA Engineer shall be provided with interface shear and adhesion 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).

Leachate Drainage Stone	/	Protective Geotextile
Protective Geotextile	/	FML
FML	/	GCL
GCL	/	Engineered Clay Liner

2.5.2 The Contractor shall complete the testing 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.

2.5.3 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 utilities will be removed by the site operator prior to the works.

2.7 Environmental Considerations

2.7.1 Mud

The Contractor shall use his best endeavours to ensure that the Site entrance, site haul roads, private and public highways remain free from the deposition of mud from his vehicles. Should any of the Contractor's vehicles deposit mud in any of the above areas the Contractor shall arrange for its immediate removal.

2.7.2 Dust

The Contractor shall use his best endeavours to ensure that all working areas, temporary haul roads, Site entrance, private and public highways remain free from dust. Water bowsers and mechanical road sweepers shall be deployed during prolonged periods of dry weather and at the Engineer's discretion.

2.7.3 Noise on Site

The Contractor shall employ the best practicable means as defined in the Control of Pollution Act 1974 to minimise noise and vibration resulting from his operations. Particularly the Contractor shall ensure that all vehicles, plant and machinery used during the operations are fitted with effective exhaust silencers and that all parts of such

vehicles, plant and machinery are maintained in good repair. Additionally, the engines of vehicles and plant which will be out of use for a period exceeding 15 minutes shall be turned off, or where this is impracticable, shall be throttled back to a minimum.

2.7.4 Water

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 the adjacent Lagoon via a route agreed with the Engineer on site.

The Contractor shall ensure that no runoff from his works is discharged from the Site untreated.

The Contractor shall pay particular attention to surface water flows into the Works area from either the previously capped slope adjacent to the north of Cell 10 or the current access road. The Contractor shall take appropriate measures to divert runoff from these slopes.

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 at the Contractors expense.

2.7.5 Nuisance to Residents

The Contractor shall use his best endeavours to prevent his operations becoming a nuisance to the local residents. If, for any reason, complaints from the local residents occur, these shall be duly recorded and brought to the immediate attention of the Contractor who shall agree with the Engineer to review, and if appropriate, revise his method of working.

2.7.6 Escape of Leachate

The Contractor shall exercise extreme care when working adjacent to the existing Cells and shall not cause extra perforations to occur within any capping / lining materials. Should there be any issues of leachate the Contractor shall manage the issues by collecting the leachate and pumping it to Cell 6 or such other location as may be approved by the Engineer.

2.8 Site Security

2.8.1 The Contractor shall be responsible for organising any security which he deems to be necessary. Resources Management UK Ltd will not be employing a watchman to attend the Site during all non-working hours. A night watchman shall be permitted access to the Contractor's compound and Portacabin. The Contractor's security arrangements shall not compromise the Resources Management UK Ltd security system. All arrangements including nominated Site gate key holder, name of security company, hours of cover and procedures shall be agreed with the Engineer in writing.

2.9 Contract Organisation/Definition of Site Area

2.9.1 The Contract shall be organised as follows:

Employer	Resources Management UK Ltd
Design Engineer	Geotechnology Ltd
Engineer	Geotechnology Ltd
CQA Engineer	Geotechnology Ltd
Main Contractor	To be announced

Lining Sub-contractor	Celtic Lining Ltd
Pipework Supplier	MGS
Drainage Aggregate Supplier	Mason Bros

2.9.2 The Engineer shall make arrangements with Resources Management UK Ltd for the Contractor to have sole possession of the area of the landfill site in which the Works are taking place for the duration of the Works. However the Contractor shall note that there will be areas of the landfill site into which he may be required to enter for the purposes of carrying out works under this Contract, which are and will remain under the control of Resources Management UK Ltd. The Contractor shall ensure that operatives under his control conduct themselves according to the procedures and safety rules in force on those areas. The Contractor and his staff shall participate in joint safety inductions, which shall be arranged by Resources Management UK Ltd for landfill site procedures and the Contractor shall arrange joint inductions for his staff and Resources Management UK Ltd staff for construction site procedures.

2.9.3 The area of the Site under the control of the Contractor shall be delineated using high visibility bunting or similar material approved by the Engineer supported on road pins or wooden fence posts. All this material shall be removed at the end of the Contract.

2.9.4 The Contractor shall afford full and free access to the Employer or any of his agents or contractors employed in carrying out any supplementary works on the Site. The Contractor shall note that in matters of judgement on compliance of any of the Contractor's activities with the Waste Management Site Permit the Site Manager shall have absolute authority and his decision will be final.

2.9.5 No claim will be entertained in respect of any delay suffered by the Contractor due to his nonexclusive use of parts of the Site or his non-compliance with the Environmental Permit.

2.9.6 The Contractor shall provide a Site Supervisor 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.

2.9.7 Progress meetings shall be held weekly, 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.

2.10 Accommodation for the Engineer

2.10.1 The Contractor shall supply suitable site accommodation for the use of the Engineer.

2.11 Technical Query Register

2.11.1 The Contractor shall prepare a Technical Query register. This register shall be the early notification device for all construction queries, requests for additional information and notifications of any intention for claims for extensions of time etc. The Contractor shall gain approval of the Technical Query Register Template from the Engineer prior to its implementation.

3 EXCAVATION AND BACKFILLING TO ACHIEVE FORMATION

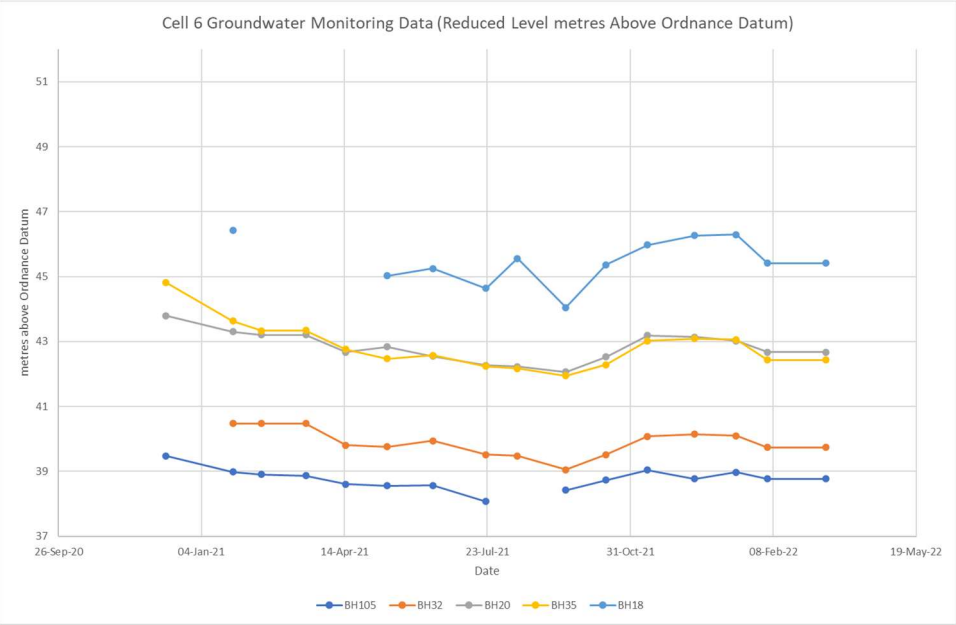
3.1 Pre-Operational Condition 2 – Engineered Unsaturated Zone

3.1.1 Permit conditions require that new cells have a minimum unsaturated zone thickness beneath the AEGB of 1.0m to provide the attenuation required by the design. Pre-operational Condition 1 requires that a ground investigation is carried out to determine the thickness of the unsaturated zone beneath any proposed new cells and POC 2 requires that any control measures required to maintain groundwater levels are determined on the basis of at least 12 months monitoring data.

3.1.2 A comprehensive ground investigation has been undertaken by TerraConsult including the installation of groundwater monitoring infrastructure in the vicinity of Cells 6-10. The data from the ground investigation and a schedule of the installed wells is found in TerraConsult's report: Withyhedge Landfill Site, Installation of Groundwater Monitoring Boreholes, Validation Report dated December 2020.

3.1.3 POC 2 requires a review of groundwater monitoring data to be undertaken to determine what control measures (if any) are required to maintain an unsaturated zone of 1.0m beneath the proposed cell. At the time that Cell 6 was proposed only limited data was available and in recognising this shortage of data, the cell was designed to have an unsaturated zone thickness of 1.5m. However, monitoring has continued since the installation of the wells and a more comprehensive dataset is now available.

3.1.4 An examination of the groundwater level monitoring records from boreholes in the vicinity of Cells 6-10 shown on the graph below reveals that water levels increase by 1 to 2 metres in the winter period and drop during the summer period. The graph clearly indicates that selecting wintertime groundwater levels is the appropriate choice when considering the unsaturated zone thickness as the highest groundwater levels will result in the thinnest unsaturated zone. The graph covers the period from installation in late 2020 to March 2022, exceeding the 12 months required.



3.1.5 Geotechnology has reviewed the data from dipping of all the monitoring infrastructure, including the boreholes in the vicinity of Cell 10. This allowed a site wide groundwater surface to be established at a time when time series monitoring data (shown above)

indicates groundwater maxima. In addition to the groundwater boreholes, three trial pits were excavated within the footprint of Cell 10 to provide additional groundwater level data. The data from the independent sweep of boreholes, combine with the trial pit data, was used to produce a groundwater surface plan, and this is shown as contour lines on groundwater elevation on drawing 2267/4.

3.1.6 The design of the formation levels for Cell 10 has been carried out by setting the base level at an elevation that will ensure a minimum unsaturated zone of 1.2m. Drawing 2267/4 also shows the unsaturated zone thickness beneath the cell footprint as a series of elevation contours across the floor of the cell. The minimum UZ thickness is shown to be 1.2m.

3.1.7 The combination of a design based upon an independently acquired January groundwater surface together with a time series analysis of routine monitoring data indicates that the design unsaturated zone for Cell 10 of 1.2m is robust and that no specific control measures are required to maintain levels. Accordingly, this is considered to meet the requirements of POC2.

3.2 Surface Water Collection and Management

3.2.1 Currently surface water in the vicinity of Cell 10 is drained towards the northwest, with surface water in the south drained through a perimeter pipe around the rim of the southern batter. Water within the cell currently gravitates northward to the lowest point of the area before draining toward the northwest to join the existing surface water ditch.

3.2.2 Surface water from the footprint of Cell 10 will be managed for the duration of the construction works by the contractor, though this is likely to be straightforward as the construction materials to formation are granular and the weather conditions in summer are more favourable. Cohesive soils will be placed only when weather conditions are suitable and these will be within the containment of the formation bunds, allowing easy collection of accumulated run-off. Surface water gathering within the cell will be pumped out to a temporary settling pond and released once settled. The footprint of Cell 10 currently receives little or no flow from adjacent ground so the management of inflowing water will not be required.

3.3 Definitions

3.3.1 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. If otherwise suitable this material shall be classified as suitable when wetted or dried sufficiently as appropriate.
- Clay of liquid limit exceeding 90% and/or plasticity index less than 10% or exceeding 65%.

"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.

3.3.2 The fill to be used in the construction of the basal formation will be in accordance with Table 3-1 below.

Table 3-1 Grading Requirements (SHW Series 600: Table 6/2)

Parameter	Test Method	Requirement
Grading: Class 1A 300 mm 125 mm 63 microns	BS 1377: Part 2 :	% Passing: 100 95-100 <15
Grading: Class 2C 125 mm 2 mm 63 microns	BS 1377: Part 2 :	% Passing: 100 15-80 15-80

3.4 Formation Level – General

3.4.1 The Contractor shall undertake a pre start topographic survey to check that the topographic levels of each cell are to the contours shown on the Drawings. If differences are found, then the Contractor shall report directly to the engineer. The effect of any differences will be agreed by the Contractor and Engineer.

3.4.2 Drawing 2511/9 and 2511/10 show design sections through the phase, whilst drawing 2511/3 shows the formation levels to be achieved. The formation will be primarily composed of cut faces and areas of filling. It may be that hard strata are encountered during the Works; the Contractor shall provide excavation machinery capable of undertaking this task.

3.4.3 After undertaking any requisite enabling works (site clearance) to remove topsoil, any remaining sludge or rock the Contractor shall prepare the formation by cut and fill activities. The formation level shall be prepared by the placement and compaction of excavated or stockpiled material. The compaction requirement for this material has been taken from the Highway Agency's Specification for Highway Works.

3.4.4 Where filling with site won / imported cohesive material becomes necessary the formation level shall be prepared such that it achieves the minimum shear strength as

set out in Table 3-2 below. Where the surface is cohesive material, the Engineer shall check the finished formation level on a 25 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.

3.4.5 All soft areas shall be excavated and replaced with fill in accordance with table 3.1 or similar approved by the Engineer which shall be placed in accordance with the Highways Agency Specification for Highway Works, Series 600 in layers with 150mm maximum thickness. Each layer shall be compacted with an 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 the Engineer.

3.4.6 The Contractor shall proof roll all formation basal and sidewall surfaces immediately before any Engineered Liner is placed. Where the Engineer deems that the surface is not sufficiently competent it shall be treated as in Section 3.2.5 above.

3.4.7 With the exception of excavation for the leachate extraction chamber or excavation of flaws above, the Contractor shall not excavate below the formation level indicated in Drawing 2067/3.

3.4.8 The Contractor shall organize haul roads such that the formation level of the Works receives minimum traffic and suffers no rutting or other damage.

3.5 Formation – Excavation

3.5.1 Where excavation is required to prepare the formation the Contractor shall selectively excavate material to the formation level indicated on Drawing 2511/3. All finished excavated faces shall be no steeper than 1 (v) to 2 (h). The tolerance for achieving design level is +0mm -50mm.

3.5.2 The Contractor shall selectively excavate the material including hard dug material available to produce:-

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

3.6 Disposal of Excavated Material

3.6.1 The Contractor shall remove all material excavated either:-

to the formation filling operation or;
an area agreed in advance with the Engineer.

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

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

3.7 Engineered Fill – Backfill Operations

3.7.1 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.

3.7.2 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.

3.7.3 Class 1 and Class 2 backfill materials 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, at the Contractor's expense.

3.7.4 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, as revised following the results of compaction trials. The Contractor shall be required to provide to the Engineer a detailed method statement for the construction of backfill soils for approval prior to the Works starting. Compaction shall be in accordance with Appendix 6/1 of the Highway Agency's Specification for Highway Works, modified by the results of field trials.

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

3.7.6 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.

3.7.7 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.

3.7.8 Where cohesive material is used it shall be placed so that the minimum shear strength in Table 3-2 below is achieved as measured by the Engineer with a hand shear vane. Class 2 material shall be tested for moisture and density; the results from which are to indicate that the material has been compacted with a maximum of 7.5% air voids at a moisture content no lower than its plastic limit. The frequency of measurement shall be in accordance with the requirements set out in Table 3-2. The Engineer shall also observe the placement of the Class 2 material and record the compactive effort applied to each layer.

3.7.9 Fill shall be site won from the excavation operations described in Clause 3.

Table 3-2 Engineered Fill Testing Requirements

Property	Test Method	Units	Testing Frequency	Requirement
Shear Strength (in cohesive material)	Hand Shear Vane in accordance with Manufacturer's Instructions	kPa	25m grid on finished formation surface and intermediate fill layers in cohesive material	$\geq$45
Moisture content (in cohesive material)	ASTM D4643 – microwave method	%	1 test per 1000m^3	$\geq$ Plastic limit
Moisture / Density Plot (in cohesive material)	Core cutter and or large scale gravel replacement density test	% and Kg/m^3	1 test per 1000m^3	$\leq$ 5% air voids
Compaction	Visual observation of layer thickness and compactive effort	NA	Three per Day	To satisfaction of CQA Engineer

3.8 Compaction Trials

3.8.1 Separate compaction trials are to be carried out for each main material type proposed to be placed and compacted to form the engineered backfill.

- The trial area shall be located in agreement with the Engineer.
- The dimensions of the test area shall be at least 20 metres long excluding any necessary approach ramps formed to allow the operation of earthmoving and compaction plant over the trial area. The width of the trial area shall be a minimum of 4.0 metres with shoulders 1.0 m wide on both sides, which is a minimum overall width of 6.0m.
- All materials used in the compaction trials shall be obtained from the stockpiles of materials that it is proposed shall be used in the construction of the main infilling.
- The fill shall be spread in layers of a thickness in accordance with the recommendations made in the Highway Agency's Specification for Highway Works. The materials shall then be compacted with the same number of passes on each lane using the type of compaction plant it is proposed shall be used in compacting the materials in the Works.
- The degree of compaction achieved by the compaction plant shall be monitored by means of settlement observations.
- Class 2C materials only – Density determinations shall be made on the layers of fill materials which have been spread, levelled and compacted on top of a compacted layer of the same material. The density of the underlying layer shall be at least that of the layer on which the density determinations are to be made.
- The roller speed shall be determined before the tests and carefully checked. A suitable rolling speed for a vibrating roller operating on a rock fill is 4 km/h. If it is found that difficulties are experienced in achieving the specified density using the initially determined speed, further tests shall be carried out using a lower speed. Similarly, if it is found that the specified density is easily achieved further tests shall be carried out at a higher speed.

- Once the requirements for achieving the specified density have been determined for a specific layer thickness the CQA Engineer may decide, at his discretion, to carry out further tests on different thicknesses of spread materials.

3.9 Engineered Fill – Remediation

3.9.1 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, an area within a 7.5m 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.

3.9.2 Should the compacted Class 1 fill material not have been compacted in accordance with this Specification the Engineer shall designate the limits to the area in non-compliance to the Contractor. The Contractor shall re-compact the area or replace the designated material and compact to meet the requirements of this Specification.

3.9.3 The Contractor shall take all reasonable precautions against prepared areas being flooded or waterlogged. In the event of surface deterioration by any cause the Engineer may direct the Contractor to trim, scarify and roll the formation as appropriate. The Contractor will be required to excavate and replace all material, which has in the opinion of the Engineer become unsuitable.

3.9.4 The Contractor shall remove or split all particles of a size greater than the maximum allowed at Table 3-1 encountered in the fill.

3.9.5 Non-compliant material shall either be replaced with compliant material or treated / processed using techniques / methods agreed with the CQA Engineer. The material excavated shall be removed to stockpile at a location to be agreed with the CQA Engineer.

4 ENGINEERED MINERAL LINER (EML)

4.1 General

4.1.1 The Contractor shall supply and place the approved clay liner material to a thickness of 0.5 metres with a permeability of 1 x 10^{-9} m/s or less.

4.1.2 The Contractor shall provide a Source Characterisation Report prepared by a suitably qualified Geologist or Engineer for presentation to NRW for each liner material 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;
- Multistage quick undrained shear strength : BS1377 : Part 7 : Method 7.
- The source testing should be undertaken at a frequency of 1 testing suite per 2500m^3 or a minimum of 3 suites per source.

4.1.3 The Engineer will require access to inspect the proposed liner material 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 Cells as shown and in accordance with the detail on the Drawings. The liner material shall be compacted to a minimum thickness as set out in Table 4-1 below. The Contractor shall condition the liner material by the provision and application of sufficient water and / or working the liner material to ensure that the moisture content of the liner material is satisfactory to achieve the required compaction whilst maintaining sufficient shear strength.

Table 4-1 Requirements for Engineered Liner Thickness

Application	Engineered Liner Thickness (mm)	Total Thickness (mm)
Basal Liner	500	500
Sidewall Liner	500	500

4.1.5 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 material is laid and compacted onto any areas proved not to be thick enough in accordance with the requirements of the Contract.

4.1.6 Independent surveys are required to verify the Contractor's surveys. The independent survey will be carried out by CQA staff and will cover the whole of the works area at a density of points to provide evidence of compliance. The independent survey points shall be well spread across the Site and shall include any leachate extraction / monitoring point sumps. The Contractor shall give 4 days prior notice to the client of the programmed availability of areas to check.

4.2 Formation/Subgrade Surface

4.2.1 The Contractor shall ensure that the surface is free of:

- Vegetation and putrescible material;
- Objects that would protrude into the engineered liner by more than 25 mm;
- 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 Clause 3.2 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 Liner is laid.

4.2.3 The subgrade shall be surveyed in accordance with Clause 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 Liner shall not be constructed on areas of subgrade which have not been approved by the Engineer. In cohesive soil, the subgrade shall have a shear strength of 50 kN measured on a 25m grid. In granular material, the subgrade shall be proof rolled to demonstrate its competence.

4.3 Method Statement

4.3.1 At the commencement of the Contract the Contractor shall provide a detailed Method Statement and Quality Control Programme for the construction of the Engineered Liner. The Method Statement shall include a programme giving full details of both type and quantity of all of the items of construction plant the Contractor proposes to use and the proposed order of carrying out the Works. The Quality Control Programme shall clearly show how a consistent quality liner is to be produced and the means of detecting reductions in quality of liner material.

4.4 Engineered Liner Specification

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

- The permeability of the clay liner shall not be greater than 1×10^{-9} m/s.
- The material shall have a minimum fines content (defined as particles finer than 0.063 mm) of more than or equal to 20%.
- The material shall have a minimum clay content (defined as particles finer than 0.002 mm) of more than or equal to 8%.
- The material shall have a maximum gravel content (defined as particles coarser than 5mm) of less than or equal to 30%.
- The liquid limit shall not exceed or be equal to 90%.
- The plasticity index shall be not less than or equal to 10% and not greater than or equal to 65%.
- The Engineered Liner thickness shall be 500mm measured perpendicular to its

surface.

- The maximum stone size shall not exceed 125 mm.
- The material shall be compacted such that the material contains no more than 7.5% 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.
- The shear strength of the basal liner shall be a minimum of 50 kPa and the shear strength of the sidewall liner shall be a minimum of 70 kPa.

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

4.5 Engineered Liner Trial

4.5.1 The Contractor shall undertake a field trial to prove that the proposed 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.

4.5.2 The contractor shall complete the trial utilising the material proposed as the main lining material. The moisture content of the material 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 liner and to allow sufficient spread of test and sampling locations. The trial liner shall consist of 2 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 liner shall be subdivided into four, and within each quadrant the Engineer will test the trial liner in accordance with LFE4. Where the results show that methodology and plant used to place the trial liner achieve the required specification, the Engineer will issue written approval and works may proceed with placement of the 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 Natural Resources Wales.

4.6 Engineered Liner Construction

4.6.1 The Contractor shall construct the Engineered Liner using the plant and methodology defined in the Contractor's Method Statement, modified as necessary in response to the field trial results.

4.6.2 The Contractor shall ensure that:

- The liner is placed in separate layers such that when compacted, each layer is no greater than a nominal 250 mm thick;
- The surface of each layer is scarified to a nominal depth of 25 mm prior to the placement of any subsequent layer of Engineered Liner;

4.6.3 The Contractor shall inform the Engineer when areas of Engineered Liner layers have been completed prior to scarifying. Where the results show that Engineered Liner achieves the required specification the Engineer will confirm that 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 Clause 4.7 below shall apply.

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

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

4.6.7 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 Clause 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 Clause 4.4 above.

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

- core cutter sample locations
- permeability sample locations
- nuclear density meter test hole locations
- disturbed bulk sample locations

4.7 Compliance Testing

4.7.1 The Contractor shall inform the Engineer when an area of 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 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" should be taken as 90% "sites over a sensitive (minor) aquifer (secondary Aquifer A).

4.7.3 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:

- Adjustment of the liner 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
- 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
- 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.

4.8 Contractors Quality Control Requirements

4.8.1 The Contractor shall keep daily records of the progress of laying the liner. Copies of these records shall be submitted to the Engineer on the following working day. The daily records shall include:

- date;
- progress against programme
- area and location of liner installation;
- layer thickness;
- source of clay
- plant and men undertaking liner placement.
- weather.

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 Liner Layer and in accordance with the detail shown on the Drawings. A suitably qualified and experienced Contractor shall install the GCL.

5.2 GCL Material

5.2.1 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 5-1.

Table 5-1 Requirements for Engineered Liner Thickness

Parameter	Test Method	Requirement	Test Frequency
GCL SHEET			
Thickness	ASTM D 5199/EN ISO 14196	6mm	N/A
Mass per unit area of GCL reported at natural moisture content 15%	EN ISO 14196	>5,000g/m^2	1 per 1,000m^2
CBR puncture resistance of GCL	BS 6906/EN 12236	>1100 N	1 per roll or 1 per 2,000m^2
Peel Strength	ASTM D4632	>36 N/10cm (min.)	1 per roll, 2,000m^2 or 500 on slopes > 1:3
Tensile Strength (md)	EN ISO 10319/ASTM D4595	10.5kN/m	1 per roll or 1 per 2,000m^2
Index flux	DIN 18130/ ASTM D5887	5 x 10^{-9} $m^3/m^2/s$ (max)	1 per 10,000m^2 But at least 1 per site
Hydraulic Conductivity	ASTM D5887 (distilled water @ 35 kPa confining stress)	2 x 10^{-11} m/s	1 per 10,000m^2 But at least 1 per site
BENTONITE LAYER			
Mass per unit area of bentonite component reported at natural moisture content 15%	EN ISO 14196	4,670g/m^2 (min.)	1 per 2,500m^2
Montmorillonite Content	VDG P69/XRD	70% (min.)	1 per 20,000m^2 But at least 1 per site
Cation Exchange Capacity	Methylene Blue (EA Guidance on GCBs App. A)	300 mg/g (min)	1 per 2,000m^2
Moisture content of bentonite	DIN 18121 /ASTM D4643	15 % (max)	N/A
Free swell	ASTM D5890	24 ml / 2g (min.)	1 per roll or 1 per 2,000m^2
Water absorption	ASTM D8591	600% (min.)	1 per roll or 1 per 2,000m^2
Fluid loss	ASTM D5891	18 ml in 30 min. (max.)	N/A
GEOTEXTILES			
Mass per unit area of non-woven geotextile	EN 965	200 g/m^2 (min.)	N/A
Mass per unit area of woven geotextile	EN 965	100 g/m^2 (min.)	N/A

5.2.2 The interface shear strength of the Geosynthetic Clay Layer and the Engineered Clay Layer shall be confirmed by direct shear 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 CQA Plan reproduced on Table 5-2 below. 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.

Table 5-2 Geotextile Clay Liner Conformance Testing Requirements (after LFE3)

Test description	European test method	ASTM test method	Minimum frequency of test
Mass per unit area of GCL	EN 14196		1 per 1,000 m^2
Mass per unit area of clay component of GCL at manufacturers stated moisture content	EN 14196	D 5993	1 per 2,000m^2
Peel strength$_3$ (for needle punched products only) (MD only)	EN ISO 13426-2	D 6496	1 per 2,000 m^2
Moisture content of clay	DIN 18121	D 2216	1 per 1,000 m^2
Swell index/free swell of clay		D 5890	1 per 2,000 m^2
Water absorption	DIN18132 Enslin Neff	E946	1 per 2,000 m^2
Tensile strength (MD only)$_1$	ISO 10139	D 4595	1 per 3,000 m^2
CBR$_1$/puncture resistance of finished GCL	EN 12236	D 6241	1 per 3,000 m^2
Index Flux		D5887	1 per10,000 m^2 but at least 1 per site
Montmorillonite content	XRD		1 per 10,000 m^2 but at least 1 per site
Montmorillonite content	VDG P69		1 per 2,000m^2

The maximum value should be reported
On-site visual inspection for impregnated GCLs, on-site weighing of additional bentonite to overlaps without impregnation
The values obtained using EN ISO 13426-2 are not comparable with ASTM D6496

5.6 Surface Preparation Prior to GCL Deployment

5.6.1 The subgrade shall comprise the upper surface of the Engineered Liner, 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. Natural Resources Wales shall be informed prior to the installation of materials overlying the clay to afford opportunity for inspection.

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 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.

5.7.5 The Contractor shall ensure that the edges of the lining system are protected against water ingress which might appear between the FML and GCL.

5.7.6 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.

5.7.7 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.

5.7.8 The GCL shall be installed into an anchor trench in accordance with the Drawings. The 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.

5.7.9 The Contractor shall ensure that the GCL is not damaged by premature hydration before the required confining loading is applied. The Engineer shall ensure that the GCL and subsequent FML are covered and weighted by the placement of the leachate drainage stone within the maximum allowed period as agreed at the pre-start meeting, to be confirmed by the contractor in his programme of works.

5.7.10 The Contractor shall ensure that the overlying geomembrane liner is fully sealed and welded progressively during the installation process to prevent water ingress at geomembrane repair patches and or seams prior to forecast rainfall, weekend breaks and prior to temporary weld team demobilisation for any reason.

5.7.11 The Contractor shall place leachate drainage stone spine roads progressively during liner installation programme onto the liner system at a minimum 1m depth to provide initial loading and reduce the risk of premature hydration and or separation of GCL seams and or separation of the GCL from its subgrade. The programme for this is to be agreed with the contractor at the pre-start meeting.

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 350mm. 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 GCL 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/m^2 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.

5.10 GCL Interface Testing

5.10.1 The interface shear strength of the Geosynthetic Clay Layer and the Engineered Liner Layer shall be confirmed by laboratory testing. The shear strength parameters of each interface in the lining system shall be determined by 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.

6 HIGH DENSITY POLYETHYLENE FLEXIBLE MEMBRANE LINER (HDPE FML)

6.1 General Description

6.1.1 The Contractor shall provide and install a 2.0mm thick textured HDPE Flexible Membrane Liner (FML) on the base and the sidewalls of the cell. 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 Contractor shall attend a pre-start meeting to be held on site to discuss and agree the program 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 sheet and welding rod shall be sourced from the same resin batch to ensure compatibility and shall fully comply with the requirements of either Table 1b or 2b of the Geosynthetic Research Institute (GRI) Test Method GM17 Standard Specification.

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 on Table 6-1.

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
CE certification reference or certificate
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 6-1 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.

Table 6-1 Conformance Sampling and Testing

Property	Minimum Required Values (all values minimum average)		Test Method	Test Frequency
	Textured	**Smooth**	**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
Thickness (min. ave)	2.00mm (± 10%)	2.00mm (± 10%)		
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		
Break Strength	21kN/m	53kN/m		
Yield Elongation	12%	12%		
Break Elongation	100%	700%		
Asperity Height (min. av.)	0.4mm	n/a		
Stress Crack Resistance	500hrs	500hrs		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

6.5.2 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 Table 1b or 2b of the Geosynthetic Research Institute (GRI) Test Method GM17 Standard Specification.

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.

6.6 FML Interface Testing

6.6.1 The interface shear strength of the Engineered Clay Liner 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.

6.7 Subgrade

6.7.1 The subgrade shall comprise the upper surface of the Geosynthetic Clay Liner which shall be prepared in accordance with this Specification.

6.7.2 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.

6.7.3 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.

6.7.4 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.

6.7.5 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.

6.8 Deployment

6.8.1 The FML shall be installed in the location shown on Drawing 2067/6 and subsequent details in accordance with the agreed method statement and panel layout.

6.8.2 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). Horizontal seams shall not be permitted on the slope unless otherwise agreed with the Environment Agency and instructed by the Engineer. The Contractor will need to develop a method statement including a panel layout plan for prior approval with the Engineer.

6.8.3 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.

6.8.4 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;

6.8.5 The first 1m length of sheet from each roll shall be discarded and not incorporated within the permanent works.

6.8.6 At the perimeter of the cell on the separation bund and the perimeter bunds, the FML shall be secured as shown on Drawing 2267/9. 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.

6.8.7 Where the cell abuts existing cells via an existing intercell bund, the FML shall be secured as shown on Drawing 2267/9 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 2267/9.

6.8.8 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.

6.8.9 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.

6.9 Trial Seams (Start-Up Weld Test)

6.9.1 A trial seam (startup weld test) shall be completed

- at the start of each day
- after any welding stoppage exceeding one hour
- where weather conditions have changed, affecting the welding efficiency of the machinery

6.9.2 If any of the above conditions exist, carry out the following sequence of testing under the supervision of the Engineer:

i. A test weld greater than 3m in length. The test must be carried out under the same conditions as exist for the membrane welding. Mark the test weld and record on the appropriate CQA form with the time, date, ambient temperature, geomembrane temperature, weld temperature, speed of weld, length of weld and welding machine type and number.

ii. Cut six specimens, each 25mm wide and at least 105mm long from the weld. Test three in peel and three in shear using a hand tensiometer (qualitative only) to confirm failure of the weld takes place in the Film Tear Bond Mode (as per ASTM D6392-99). For fusion welds, test both tracks of the weld in peel. To be clear, the

mode of failure shall be yield of the sheet material outside the seam. No samples shall fail in the seam.

iii. If any specimen fails, repeat the entire operation.

iv. If any of the additional specimens fail, inspect the welding equipment reporting any defects and the corrective action taken. If you can correct the problem, the equipment may be used after two further consecutive full trial seams are achieved without failure.

v. If the equipment fails five times in any 48 hour period, returned it for repair keeping records of the service.

vi. A record of the results must form part of the validation report.

6.9.3 Trial seam shall be carried out to confirm the setup of each piece of seaming equipment proposed to be used and being 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.

6.9.4 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 setup of the particular item of seaming equipment. The Engineer shall not allow seaming of the FML to commence or recommence until successful trial seams are achieved.

6.10 Seaming

6.10.1 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.

6.10.2 All seams shall be individually numbered and recorded by the Contractor.

6.10.3 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 5ºC and 35ºC;
- 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.

6.10.4 The Engineer shall measure FML sheet temperature. Any seaming undertaken on sheet with a temperature below 5ºC or above 35ºC shall be demonstrated to be of the same standard as that undertaken between 5ºC and 35ºC. 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 5ºC and 35ºC. NRWE shall be consulted for acceptance.

6.10.5 A separate procedure shall be agreed with NRW for the management of CQA for the welding of FML where the temperature of the sheet is greater than 35ºC or less than 5ºC.

6.10.6 Only suitably qualified, trained and experienced staff shall install the geomembrane liner. This must include both of the following:

i. a lead technician and a foreman accredited to at least standard level (level 1) of the BGA/TWI/CSWIP welding standard (developed by the British Geomembrane Association (BGA), Thermal Welding Institute (TWI) and the Certification Scheme for Welding Inspection Personnel (CSWIP))
ii. all welders accredited to a minimum of entry level (level 2) of the BGA/TWI/CSWIP welding standard

6.10.7 In addition, the main contractor must use a company that is accredited, or working towards being accredited, to the BGA accreditation scheme for geomembrane installers.

6.10.8 The Contractor shall provide the Engineer with the relevant details of his proposed sub-contractor and its personnel and their experience including for primary evidence of compliance with the above accreditation requirements.

6.10.9 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 Site Supervisor or 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.

Fusion (hot wedge) Welding

6.10.10 The Contractor shall ensure that:

i. the conditions detailed at section 6.10.3 above are met prior to the commencement of seaming;
ii. the Engineer is assisted in the keeping of records for the weld times and weld temperatures to enable calculation of the weld speed;
iii. 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;
iv. 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;
v. adequate temporary anchorage is provided to ensure no movement occurs during seaming;
vi. no full width horizontal seams occur on slopes;
vii. the weld temperature and speed are the same as those used when the trial seam was passed.

Extrusion Welding

6.10.11 The Contractor shall ensure that:

i. the conditions detailed at section 6.10.3 above are met prior to the commencement of seaming;
ii. the area to be welded is adequately buffed (no more than 10% of the sheet thickness shall be removed);
iii. grinding does not extend beyond the edges of the weld;
iv. prior to forming an extrusion seam, adjacent panels shall be temporarily secured by heat bonding;
v. 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.
vi. temporary bonding using adhesives shall not be permitted.
vii. a copper wire is placed at the join of the two FML sheets if HVE testing is to be undertaken;
viii. when abrasions are made the weld is constructed within 1 hour;
ix. the abrasions extend no further than 10mm either side of the edge of the weld;
x. the extrudate material used shall be identical in composition to that of the FML sheet;
xi. Extrusion welding shall only be carried out when and where it is not possible to undertake fusion welding.

6.11 Non-Destructive Seam Testing

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

Air Pressure Testing

6.11.2 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.

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

6.11.4 To confirm that the full length of seam is pressurized, 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.

6.11.5 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.

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

HVE (Spark) Testing

6.11.7 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.

6.11.8 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.

Vacuum Box Testing

6.11.9 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.

6.11.10 The installation Contractor shall comply with the requirements of ASTM D5641-16 when carrying out vacuum box testing. The vacuum box shall be held in place for at least 10 seconds at each test position over the weld.

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

6.12 Qualitative Destructive Seam Testing

6.12.1 The Contractor shall cut tab samples from the ends of each completed seam 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.

6.12.2 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.

6.13 Quantitative Destructive Seam Testing

6.13.1 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.
- every seam will be destructively tested and recorded in accordance with LFE 5 Table 1, not just seams over 25m.
- 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 (e.g. statistical routine, suspicious geomembrane feature, suspicious welding techniques, etc.)

6.13.2 For fusion welding 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 Table 6-2 below. However, the Engineer may increase this frequency of sampling if test results indicate problems or poor workmanship.

Table 6-2 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 per 200m of seam
Shear Elongation	ASTM 6392	%	50 (min)	1 per 200m of seam
Peel Strength	ASTM 6392	N/mm	21 (min)	1 per 200m of seam
Peel Separation	ASTM 6392	%	25 (max)	1 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)	

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

6.13.4 For extrusion welding the Contractor shall cut three 1,000mm long by 300mm wide seam samples from a length of weld formed separately to the weld itself using the actual FML being welded. The test weld must be formed contemporaneously and specifically for the purpose of destructive sampling. The sample weld shall be formed at the time of the weld to be tested, using the same equipment and welder operative and from the same materials used to form the weld. Two samples 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 6.13.1 above and Table 6-2. However, the Engineer may increase this frequency of sampling if test results indicate problems or poor workmanship.

6.13.5 The samples shall be forwarded to the independent testing laboratory for testing.

6.13.6 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.

6.13.7 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.

6.13.8 The minimum acceptable values to be obtained in the destructive seam tests are those indicated in GRI – GM19a and Table 6-2 above. At least five specimens will be tested for each test method. Specimens will be selected alternately by test from the samples (e.g. peel, shear, peel, shear, etc.).

6.13.9 A destructive test failure is deemed to occur if:

i. Any one of the five specimens fail in "peel separation" OR

ii. Any one of the five specimens fail in "shear elongation"

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

6.13.11 In the event of a test failure, the Contractor shall have the following options:

Fusion Welding

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.

Extrusion Welding – 25m Weld Daily Test Sample

One of the archive samples kept by the Engineer shall be tested by the laboratory. If the second sample passes, then the extrusion welding shall be deemed to have passed. If the second sample fails, then the Engineer shall establish the length of extrusion weld formed during the day tested and the seams shall be reconstructed.

Extrusion Welding – 200m Weld Test Sample

One of the archive samples kept by the Engineer shall be tested by the laboratory. If the second sample passes, then the extrusion welding shall be deemed to have passed. If the second sample fails, then the Engineer shall instruct the collection of tab samples for shear / peel testing at three random locations of the in situ weld within the 200m length being tested. If these additional samples pass the field tests, then full laboratory samples shall be taken from each of the three locations. If these laboratory samples pass the tests, then the seam shall be reconstructed between these locations by capping. If any of the samples fail, 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.

6.14 Repair Procedure

6.14.1 Faulty work, determined by inspection or testing, shall be repaired with a hand extruder, where approved by the Engineer, as follows:

- In the case of point faults, an additional layer of extrudate shall be applied;
- Large faults shall be cut back to give clean and dry interfaces, free from imperfections. They shall then be covered with appropriate shaped pieces of the same material as the liner to give a minimum 150mm overlap which shall then be welded by extrusion welding, all as specified above. Repairs for making good areas removed for random samples for destructive testing shall also be carried out by this method.

6.14.2 The Contractor shall log all repairs. Each repair shall be non-destructively tested. Repairs that pass the non-destructive test shall be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive testing, at the discretion of the Engineer. Failed tests will require the repair to be redone and retested until passing test results are obtained. The Engineer shall observe all non-destructive testing of repairs.

6.14.3 The size and shape of patches shall be such that re-heating of previously welded material is minimised.

6.14.4 All repairs shall be subject to non-destructive testing and, if deemed necessary by the Engineer, destructive testing. The Contractor shall provide to the Engineer full written records of all repairs and re-testing undertaken.

6.14.5 The Contractor shall ensure that all identified defects have been repaired and tested in accordance with this specification and that there are clear records to show that this is the case. The Contractor shall ensure that a survey measurement is taken of each and every repair.

6.15 Installation Approval

6.15.1 The installed FML shall be subject to the inspection and approval of the CQA 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.

6.15.2 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.

7 GEOTEXTILE MATERIAL

7.1 General

7.1.1 The Contractor shall supply and lay a Geofabrics HPS25 Protection Geotextile (or alternative if cylinder testing has shown its use to be acceptable) 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 the drawings.

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 criteria in Table 7-2 below:

Table 7-1 Requirements for Protection Geotextile

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	25kN 65mm	BSEN ISO 12236
Mass Per Unit Area	Kg/m^2	2.5	BS EN 965
Thickness	Mm	14	BS EN 964-1
Polymer		Polypropylene	
Bonding		Needle punched	
Construction		Non-woven or a combination of woven and 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).

7.2.2 If the Contractor wishes to propose an alternative fabric to the HPS25 already tested in combination with the locally quarried 20/40 crushed rock aggregate used on Cells 6 and 7, or an alternative source or grading of stone then the Contractor shall verify its suitability for the purpose by undertaking a cylinder test. The criteria for testing shall be as set out in Table 7-2 below.

Table 7-2 Criteria for Cylinder Testing

System	Loading
20mm - 40mm leachate drainage stone over HPS25 Protective Geotextile over 2mm HDPE	Maximum waste thickness to be 28m Restoration soil thickness to be 1m

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 mean deflection of less

than 0.25%. The Engineer will consider applications for varying geotextile properties for differing waste loadings.

7.2.3 If the Contractor proposes to use a fabric other than HPS25 and a membrane other than Solmax (GSE) 2mm textured HDPE, then 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 acceptance prior to installation of the lining system.

7.2.4 The Contractor shall supply reference samples of the proposed drainage stone (which shall be as delivered to the Site) 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 may commission parallel testing to independently verify the results of the Contractor's testing. The test shall be completed by an independent laboratory. The laboratory shall be UKAS accredited for this test. The Engineer shall, when he is satisfied that the materials proposed are compliant, issue written acceptance for the combination.

7.2.5 After issue of written acceptance, 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.

7.2.6 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 subgrade is completely cleared of any material that might harm the subgrade or the geotextile.

7.3.2 Geotextiles shall be installed in strict accordance with the Specification and Drawings, 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 accepted in writing by the Engineer prior to use.

7.3.4 Geotextiles on inclined surfaces are to be terminated as shown on the drawings.

7.3.5 The method of installation of the Geotextile shall ensure that:

- adequate temporary anchorage is provided to ensure no movement occurs during seaming;

- panels are placed one at a time;
- seaming takes place immediately following deployment.

7.3.6 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.

7.3.7 Operation of construction plant directly on the installed Geotextile shall not be permitted.

7.3.8 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.

7.3.9 Seams shall be made only by skilled and experienced operators using methods outlined by this Specification.

7.3.10 The procedure used to temporarily bond adjacent panels together shall not damage the Geotextile or the underlying FML or leachate 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.

7.4 Geotextile Contractual QA/QC Requirements

7.4.1 All geotextiles shall be accepted in writing by the Engineer, and sources of supply shall not be changed without his acceptance.

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:-

Product name and grade/no.
Name and address of producer/supplier
Batch or code number
Geotextile roll number
Roll length and width
Roll weight in kilogramme
Polymer type.
Manufacturing characteristics

7.4.3 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.

7.4.4 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 document LFE 7 "Using Nonwoven

protector geotextiles in landfill engineering" and in accordance with Table 7-3 below.

Table 7-3 Protective Geotextile Conformance Testing Requirements

Property	Test Method	Units	Typical Mean Value	Test Frequency	Tolerance
Thickness @ 2kPa	BSEN ISO 9863-1	mm	14	1/2500m^2 or part thereof	
CBR Puncture Resistance Displacement	BSEN ISO 12236	kN m	25 65	1/6000m^2 or part thereof	-10%
Tensile Strength (md)	BSEN ISO 10319	kN/m	100	1/6000m^2 or part thereof	-10%
Tensile Strength (cmd)	BSEN ISO 10319	kN/m	100	1/6000m^2 or part thereof	-10%
Extension (md)	BSEN ISO 10319	%	80	1/6000m^2 or part thereof	+/-30% of typical mean value
Extension (cmd)	BSEN ISO 10319	%	80	1/6000m^2 or part thereof	+/-30% of typical mean value
Resistance to perforation (cone drop test)	BSEN ISO 13433	mm	0	1/6000m^2 or part thereof	+2mm
Mass per unit area	BS 965	g/m^2	2500	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.

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 of 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 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.

7.6 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:-

7.6.2 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.

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

8 SUMPS AND PIPEWORK

8.1 General

8.1.1 Within Cell 10 the Contractor shall provide and install two leachate collection point (LCP), the connecting network of leachate collection and carrier drains and three leachate monitoring points (LMPs) at the locations shown on Drawing 2511/7.

8.1.2 Unless otherwise described in the Contract or agreed by the Engineer, all pipes to be used shall be black slotted single walled polypropylene or HDPE. The Contractor shall ensure that pipes are not subject to deterioration due to sunlight during the period between manufacture and installation in the Works. All pipes delivered to Site shall be stored in accordance with the manufacturer's recommendations in a compound and off the ground by means of pallets or similar.

8.1.3 The Contractor shall supply a summary of his experience in the installation and welding of leachate collection pipework.

8.2 Manufacturer's QA/QC Procedure

8.2.1 The manufacturer or supplier of pipe shall provide the following information for each separate consignment of pipes delivered to the Site:-

Product name and number
Name and address of producer/supplier
Manufacturing characteristics and constituents
Consignment number and delivery dates.
Copy of the manufacturers' recommendations for storage and installation

8.2.2 Each consignment shall be numbered, and the delivery date recorded. A consignment is considered to be the number of lengths of pipe delivered at one time.

8.3 Leachate Pipework

8.3.1 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 Drawing 2511/7. The pipes shall also be in accordance with the details in Table 8-1 below:-

Table 8-1 Leachate Pipework Criteria

Product	Specification
200mm External diameter Single Walled HDPE 125mm External diameter Single Walled HDPE	Minimum slot or perforation area of 1.5%. Pipe to be slotted evenly around its circumference

8.3.2 The Contractor shall submit the following information to the Engineer and Natural Resourced Wales for approval at least five working days prior to the installation of the leachate collection pipework:

- Details of his proposal for leachate collection pipework and fittings including proposed SDR of the pipework;
- 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 50ºC.

- Copies of the pipe manufacturers' quality control documentation;
- Copy of the manufacturers' recommendations for storage and installation;
- A summary of his experience in the installation and welding of leachate collection pipework;
- 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.

8.3.3 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.

8.3.4 No electrofusion couplers are to be used on slotted or perforated pipework. 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 as well as 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 Drainage Stone under each side ensuring that the pipe is properly bedded to provide the required support.

8.3.7 The drainage stone shall be the same material as specified in section 9 for the drainage layer adjacent to the pipe run.

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

8.4 Leachate Sump

8.4.1 The leachate sump will comprise a proprietary HDPE telescopic leachate extraction shaft manufactured by MGS. The shaft will have an internal diameter of 900mm and an external diameter of 1020mm. A gravel exclusion ring will be fitted to the concrete foundation yard along with the first section of the sump. Installation shall be in accordance with manufacturer's guidelines. The leachate shaft will be connected to the leachate extraction pipework as shown on Drawing 2511/10.

9 DRAINAGE LAYER

9.1 General

9.1.1 The leachate from the waste deposited in the Cell shall be collected by a 300 mm layer of drainage aggregate. The Contractor shall supply and install a 300 mm thick layer of drainage aggregate over the entire base and up the lower part of the side slopes to the line shown on Drawing 2511/7. Where a pipe is incorporated in the drainage layer the thickness of the drainage layer over the pipe shall be increased to a minimum thickness as shown on the drawings.

9.1 Drainage Aggregate

9.2.1 Drainage Aggregate shall be fines free stone aggregate accepted by the Engineer. The Contractor shall ensure that the aggregate, as placed, complies with the specification in Tables 9-1 and 9-2 below:-

Table 9-1 Leachate Drainage Aggregate Specification

Test	Acceptance Criterial
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	$\geq 1 \times 10^{-4}$ m/s
Particle Size Distribution BS 812 Part 103	As BS 13242 (see below)

Table 9-2 Grading of Drainage Material to BS EN 13242

British Standard Sieve Size (mm)	Percentage Passing (%) (20/40mm)
63	98-100
40	80-99
31.5	20-70 (±15)
20	0-20
10	0-5

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 or pipework.

9.2 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^{-4} m/s.

9.3.2 The Engineer will sample the drainage aggregate at least every 1000m^3 placed for particle size distribution and shall evaluate the results to ensure that the grading of the drainage aggregate has not changed substantively from that stated in clause 9.2 above.

9.3 Placement

9.4.1 The Contractor shall undertake the placement of the leachate drainage blanket 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 blanket 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 360^0 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 Clause 2.4 being undertaken.

9.5 Southern Batter Drainage Geocomposite

9.5.1 The upper section of the southern batter is to be overlain with a layer of ABG Pozidrain 7D240D/NW8 double cuspated geocomposite to transmit leachate from the overlying wastes into the Cell 10 basal tray. The specification of the geocomposite was proposed and accepted during the Variation application for the Valley Cells (which abut Cell 13) and used in the construction of the 4 Valley Cells.

9.5.2 The drainage geo-composite shall have the following properties:

Table 9-3 Drainage Geo-composite Properties

PROPERTY	STANDARD	UNIT	TYPICAL MEAN VALUE	ALLOWABLE TOLERANCE TO 95% CONFIDENCE LIMITS
Thickness @ 2kPa	BS EN ISO 9863-1	mm	8.6	n/a
Static CBR Puncture resistance	BS EN ISO 12236	kN	4.3	-10%
Tensile strength (md)	BS EN ISO 10319	kN/m	19	-10%
Tensile strength (cmd)	BS EN ISO 10319	kN/m	19	-10%
Tensile Elongation (md)	BS EN ISO 10319	%	40	+/-30%
Tensile Elongation (cmd)	BS EN ISO 10319	%	50	+/-30%
In plane Water Flow @ 20 Kpa Pressure – Hydraulic Gradient =1.0	BS EN ISO 12958	l/s/m width	1.75	-20%

i) Proposed Material Datasheet

The Contractor shall supply a technical datasheet from the geo-composite manufacturer. This information shall be forwarded to the CQA Engineer for approval, prior to any material being purchased. The geo-composites shall meet or exceed the Specification given in Table 9-3.

ii) Manufacturers Quality Control Data

When approved, but before it is brought to site and prior to it being installed, the manufacturer shall provide test results for all batches of materials that will be delivered to the site demonstrating compliance with the Specification. This is deemed to be the Manufacturer's Quality Control data. The MQC documentation shall include the following:

Roll identification Number
Geotechnical Properties and Testing Frequency
Mechanical Properties and Testing Frequency
In Plan Water Flow Properties and Testing Frequency

iii) Geo-composite Conformance testing

When delivered, conformance samples of the Drainage Geo-composites shall be obtained at a rate of 1 per 6000 m^2 delivered. These samples shall be then forwarded to the nominated laboratory for testing. A strip measuring 500 mm long shall be cut from the end of each selected roll, but not including the first 1m. From this main sample, a total of 3 No. sub samples of equal size shall be obtained; one is to be retained by the Contractor, one is to be retained by the CQA Engineer and the third shall be sent to the nominated testing laboratory for testing. The samples shall be stored in an opaque bag in a cool, dark place and shall be clearly labelled with the roll number.

Prior to installation conformance testing in accordance with test methods shown in Table 9-3 shall be carried out by the nominated laboratory at a rate of 1 per 6000m^2.

The results shall be submitted to the CQA Engineer, together with the roll number and the batch or consignment numbers to which they relate. Materials not conforming to the Specification shall be re-tested and, in the event of subsequent failure, will be rejected.

If the geocomposite does not conform with the Specification for any of the properties listed above it shall be re-tested. If the sample fails upon re-test, the roll shall be rejected and the roll with numbers on either side of the failing roll shall be tested. These additional tests shall not contribute toward the compliance testing frequency. If both adjacent rolls also fail then the entire batch shall be rejected. Geo-composite material shown to be non-conforming will not comprise part of the permanent works. Any re-testing shall be at the expense of the Contractor.

If the test failure is considered likely to be due to laboratory errors, the CQA Engineer, at his discretion, may send further samples to two different laboratories. The material shall be accepted if both alternative laboratories produce passing results. Any additional testing shall be at the expense of the Contractor.

Installation of the geo-composite shall not take place until results of the conformance tests have been obtained from the independent testing laboratory and the material has been approved by the CQA Engineer for use in the permanent works. Any material

installed into the permanent works without prior conformance tests being available shall be rejected.

9.6 Leachate Drainage Layer Interface Testing

9.6.1 The Contractor shall determine the shear strength parameters of the Leachate 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 acceptance prior to installation of the lining system.

9.7 Overlap with Geocomposite Drainage Layer

9.7.1 The upper sideslopes are to be drained with a pozidrain geocomposite product. The geocomposite will discharge its leachate into the appropriate drainage blanket and to ensure intimate contact between geocomposite and drainage aggregate the aggregate is to the placed over the bottom edge of the geocomposite for a distance of 2.5m. This detail will require the drainage stone to temporarily pause 2.5m short of its final height whilst the first lifts of waste are placed into the basal tray. When geocomposite deployment is complete, the final lift of drainage aggregate will be placed over the bottom 2.5m of the geocomposite.

10 ELECTRICAL RESISTIVITY LEAK TESTING (ERLT)

10.1 General

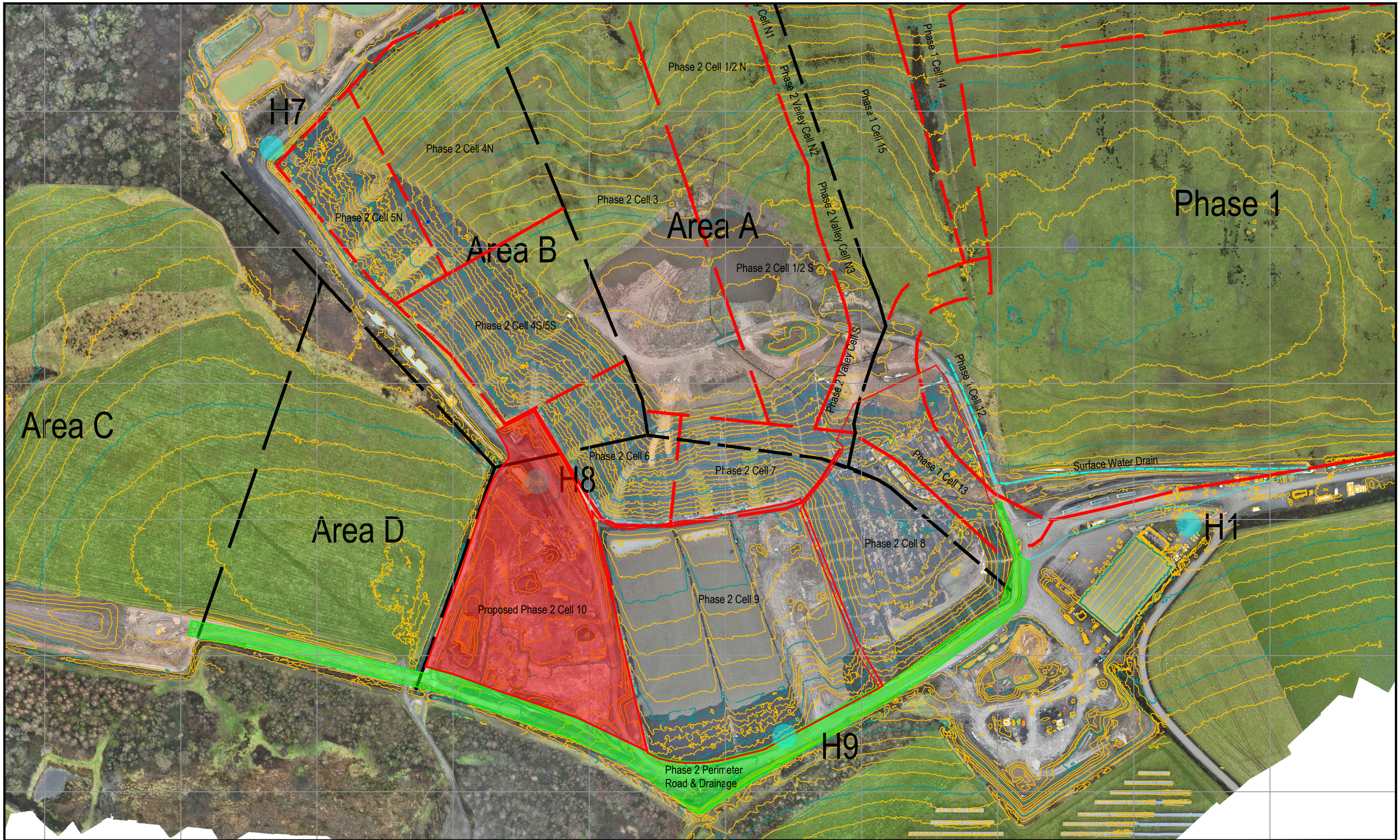
10.1.1 The Contractor shall arrange for an ERLT to be carried out by a qualified experienced sub-contractor on the area of the fully prepared FML liner after placement of protective geotextile and leachate drainage aggregate in areas where leachate drainage is required and after the placement of protective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

10.1.2 The Contractor shall ensure their method of working ensures that the liner beneath target pads can be surveyed. This will require that the drainage blanket is omitted over the target pad area to allow the ERLT survey to take place over the protective fabric. The ERLT contractor will visit site after fabric deployment to survey the concrete pad locations before concrete is cast. Concrete shall only be cast once the ERLT survey has confirmed that there are no perforations on the fml beneath the pad locations.

10.1.3 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.

10.1.4 The sub-contractor shall fully investigate all anomalies detected, including those introduced by the Engineer, 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.

10.1.5 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.



RML
RESOURCES MANAGEMENT UK LTD

LEGEND

- Proposed Footprint Cell 10
- Perimeter Road & Drainage

NOTES

Existing topography from January 2025 Drone Survey at 0.5m contour interval.

PROJECT

Withyhedge Landfill
Phase 2 Cell 10

TITLE

Cell 10 Location Plan

DRAWING NUMBER

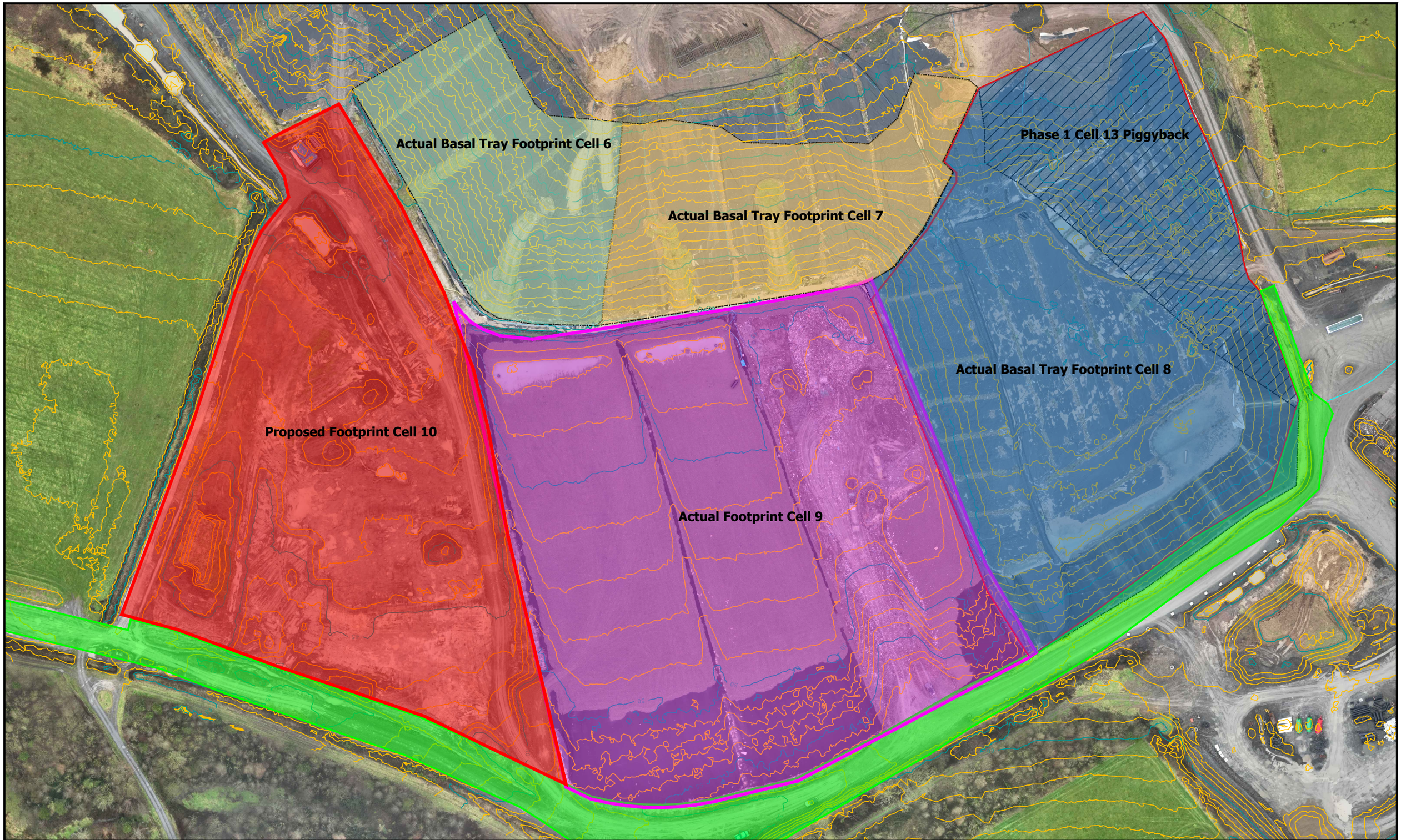
2511/1

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

NOTE

Issued for NRW Consultation

GEO TECHNOLOGY



RML
RESOURCES MANAGEMENT UK LTD

LEGEND

- As-built Footprint Cell 6
- As-built Footprint Cell 7
- As-built Footprint Cell 8
- As-built Footprint Cell 9
- Proposed Footprint Cell 10

NOTES: Existing topography from January 2025 Drone Survey at 0.5m contour interval.

PROJECT: **Withyhedge Landfill Phase 2 Cell 10**

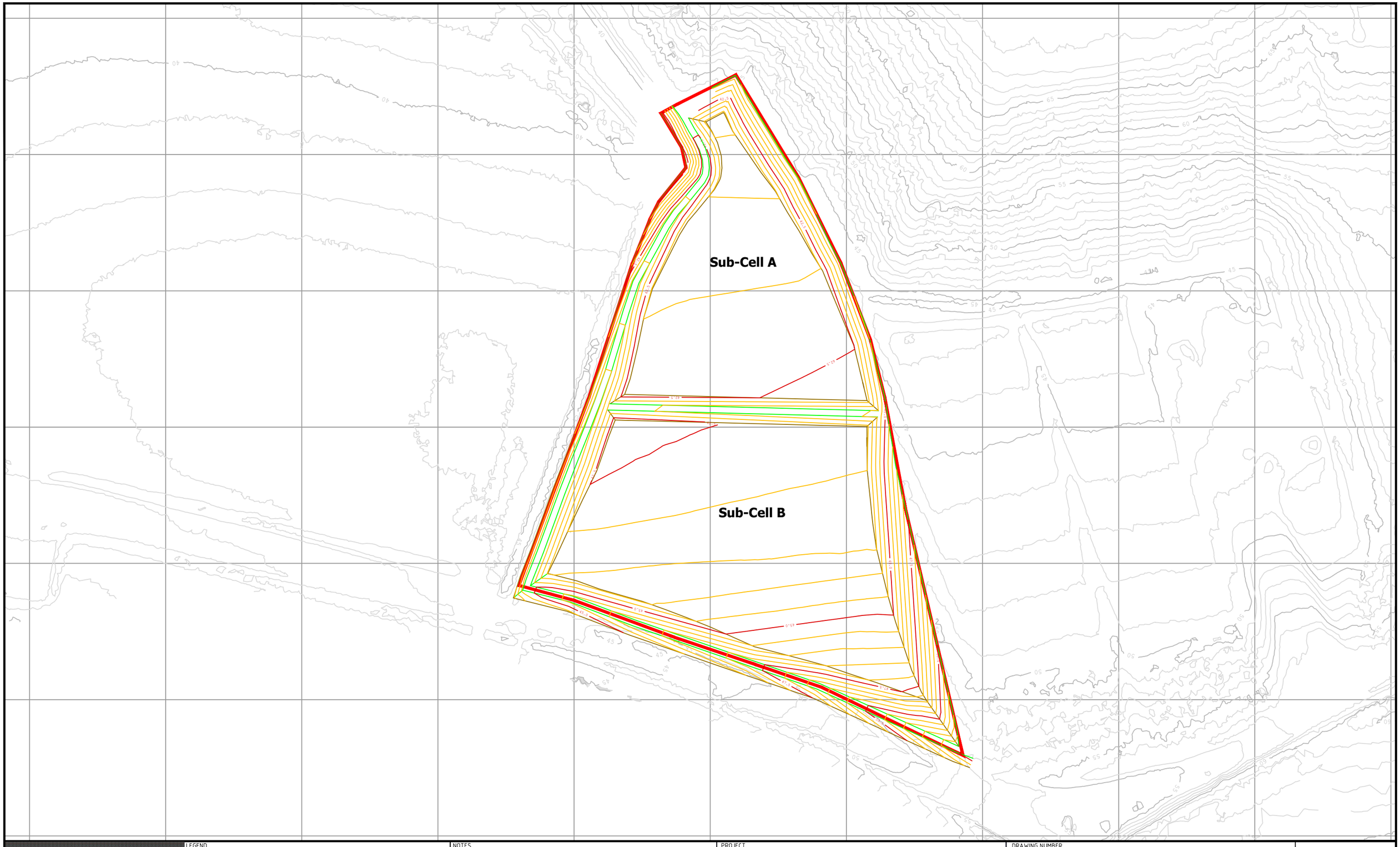
TITLE: **Footprint of Cells 6 - 10**

DRAWING NUMBER: **2511/2**

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

NOTE: **Issued for NRW Consultation**

GEO TECHNOLOGY



RML
RESOURCES MANAGEMENT UK LTD

LEGEND
- Normal Contour (0.5m)
- Prominent Contour (2.5m)
- Proposed Footprint Cell 10

NOTES
Existing topography from January 2025 Drone Survey at 0.5m contour interval.

PROJECT
Withyhedge Landfill
Phase 2 Cell 10

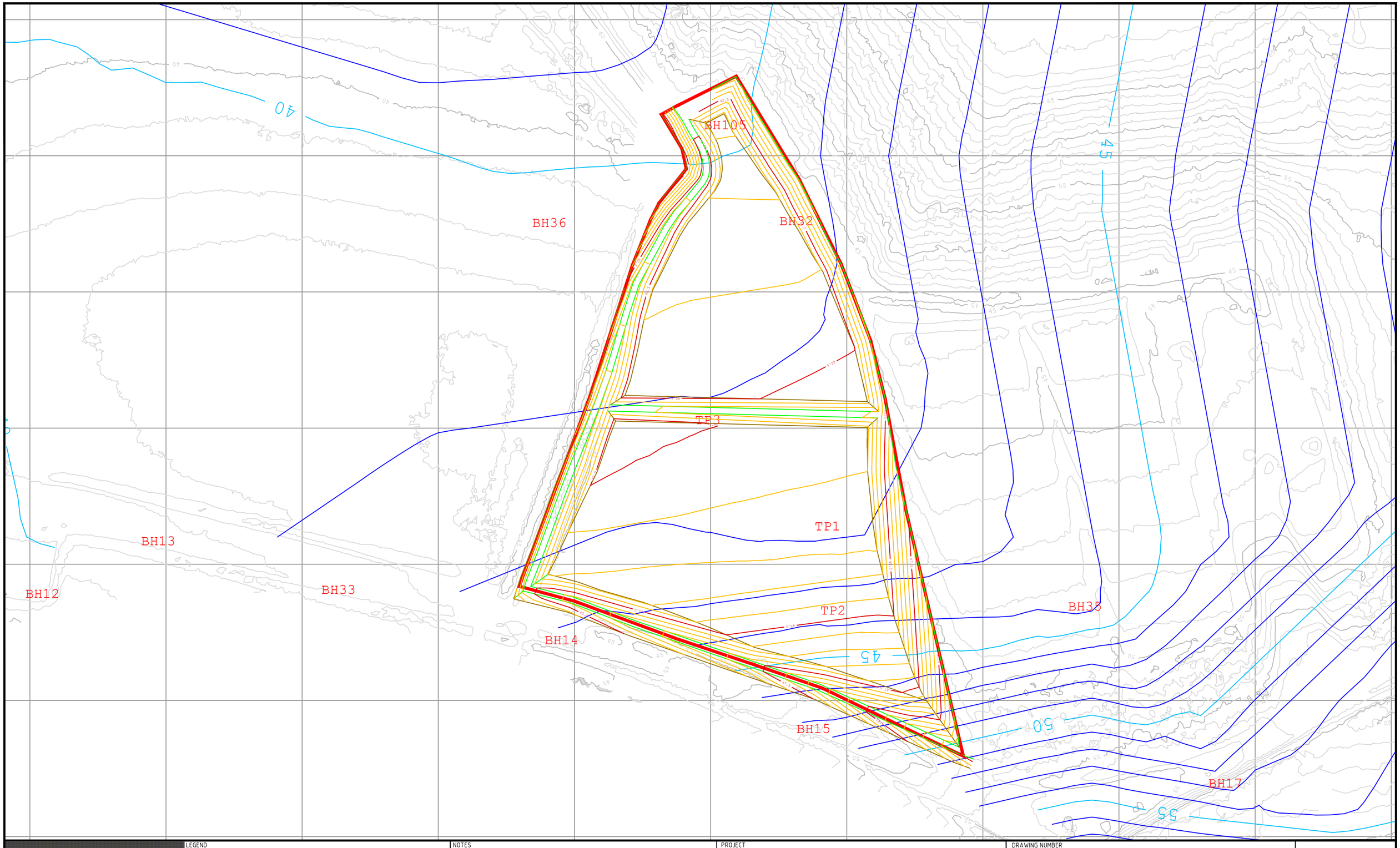
TITLE
Cell 10 Formation Levels

DRAWING NUMBER
2511/3

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

NOTE
Issued for NRW Consultation

GEO TECHNOLOGY



RML
RESOURCES MANAGEMENT UK LTD

LEGEND
- Normal Contour (0.5m)
- Prominent Contour (2.5m)
- Groundwater Contour (Jan24)

NOTES
Existing topography from January 2025 Drone Survey at 0.5m contour interval.
Design contours are Formation Levels
Groundwater levels from January 2024

BH15 GW Data Point

PROJECT
Withyhedge Landfill
Phase 2 Cell 10

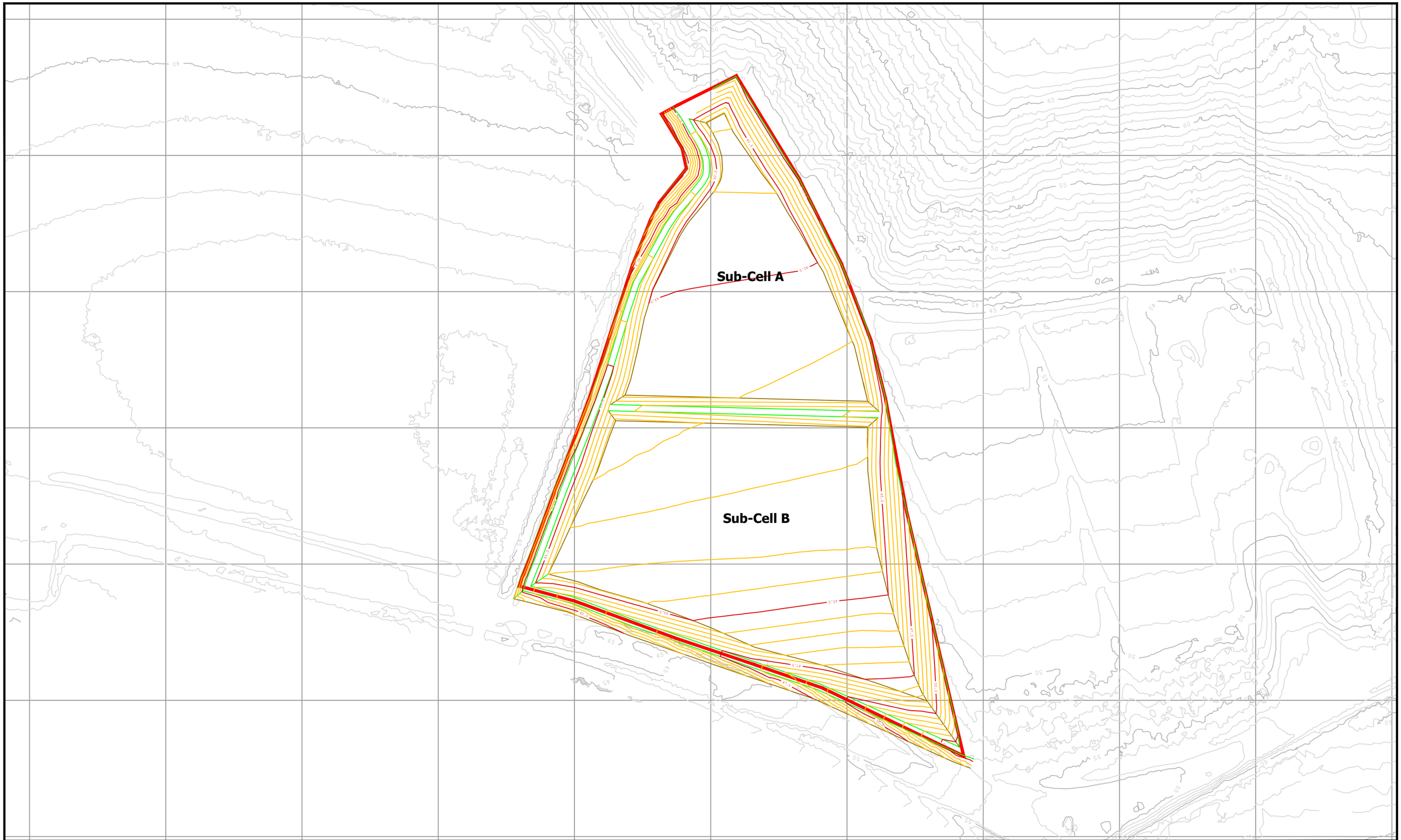
TITLE
Groundwater Levels

DRAWING NUMBER **2511/4**

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

NOTE
Issued for NRW Consultation

GEO TECHNOLOGY



RML
RESOURCES MANAGEMENT UK LTD

LEGEND

- Normal Contour (0.5m)
- Prominent Contour (2.5m)
- Proposed Footprint Cell 10

NOTES

Existing topography from January 2025 Drone Survey at 0.5m contour interval.

PROJECT

Withyhedge Landfill
Phase 2 Cell 10

TITLE

Cell 10 Top of Compacted Clay
AEGB Levels

DRAWING NUMBER **2511/5**

SCALE AT A3	DATE	DRAWN
1:1250	02.25	KJT

NOTE

Issued for NRW Consultation

GEO TECHNOLOGY

RML
RESOURCES MANAGEMENT UK LTD

LEGEND

Geosynthetic Panel

Proposed Footprint Cell 10

NOTES

Existing topography from January 2025 Drone Survey at 0.5m contour interval.

PROJECT

Withyhedge Landfill
Phase 2 Cell 10

TITLE

Typical Geosynthetic Panel Layout

DRAWING NUMBER

2511/6

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

NOTE

Issued for NRW Consultation

GEO TECHNOLOGY

RML
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LEGEND
- Spine Drain
- Spur Drain
- Normal Contour (0.5m)
- Prominent Contour (2.5m)
- 1m Compliance Level

NOTES
Existing topography from January 2025 Drone Survey at 0.5m contour interval.

PROJECT
Withyhedge Landfill
Phase 2 Cell 10

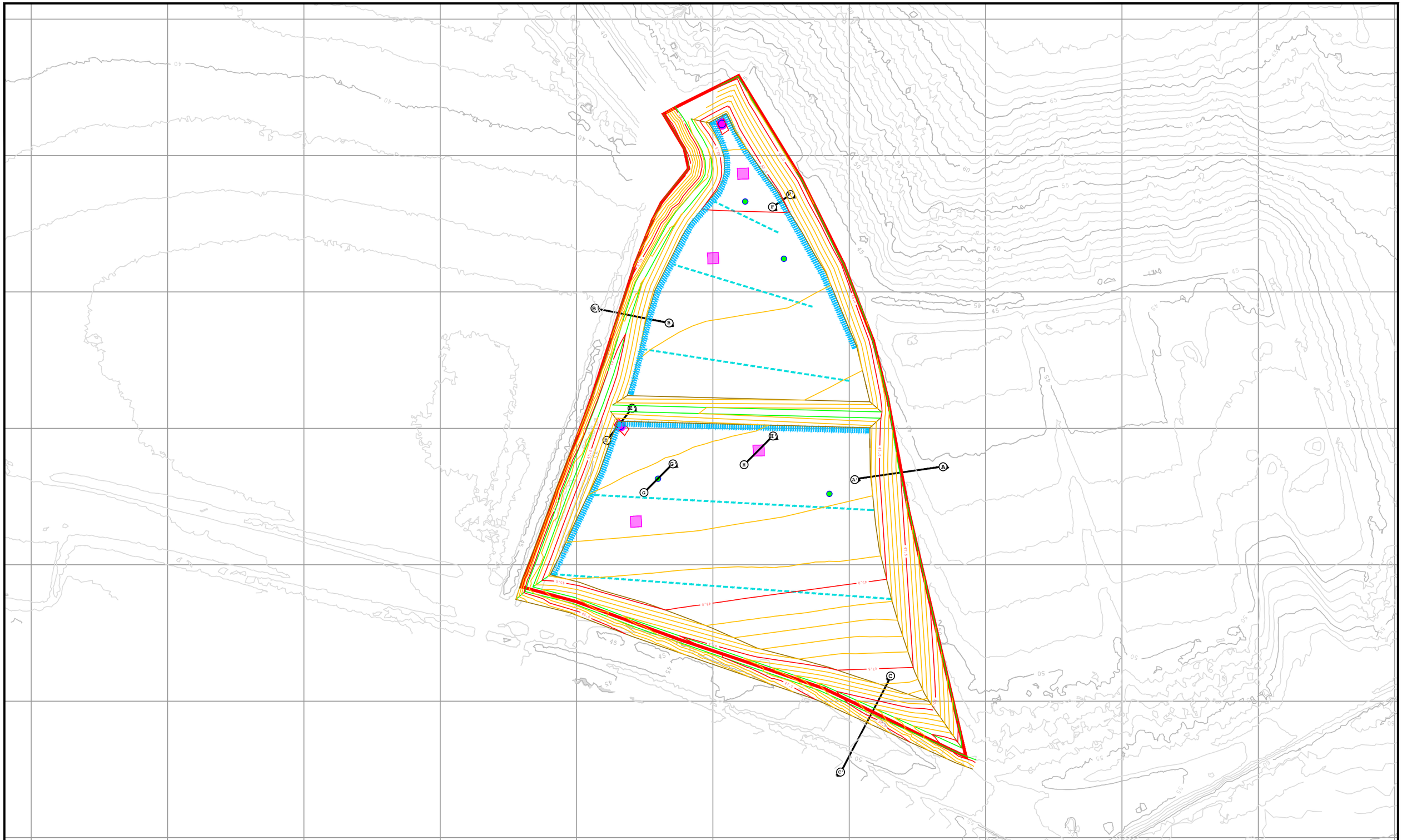
TITLE
Cell 10 Leachate Drainage Arrangements

DRAWING NUMBER
2511/7

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

NOTE
Issued for NRW Consultation

GEO TECHNOLOGY



RML
RESOURCES MANAGEMENT UK LTD

LEGEND

- Spine Drain
- Spur Drain
- Normal Contour (0.5m)
- Prominent Contour (2.5m)
- Leachate Extraction Sump
- Monitoring Target Pad
- Leachate Monitoring Well

PROJECT
Withyhedge Landfill
Phase 2 Cell 10

TITLE
Construction Detail Section Locations

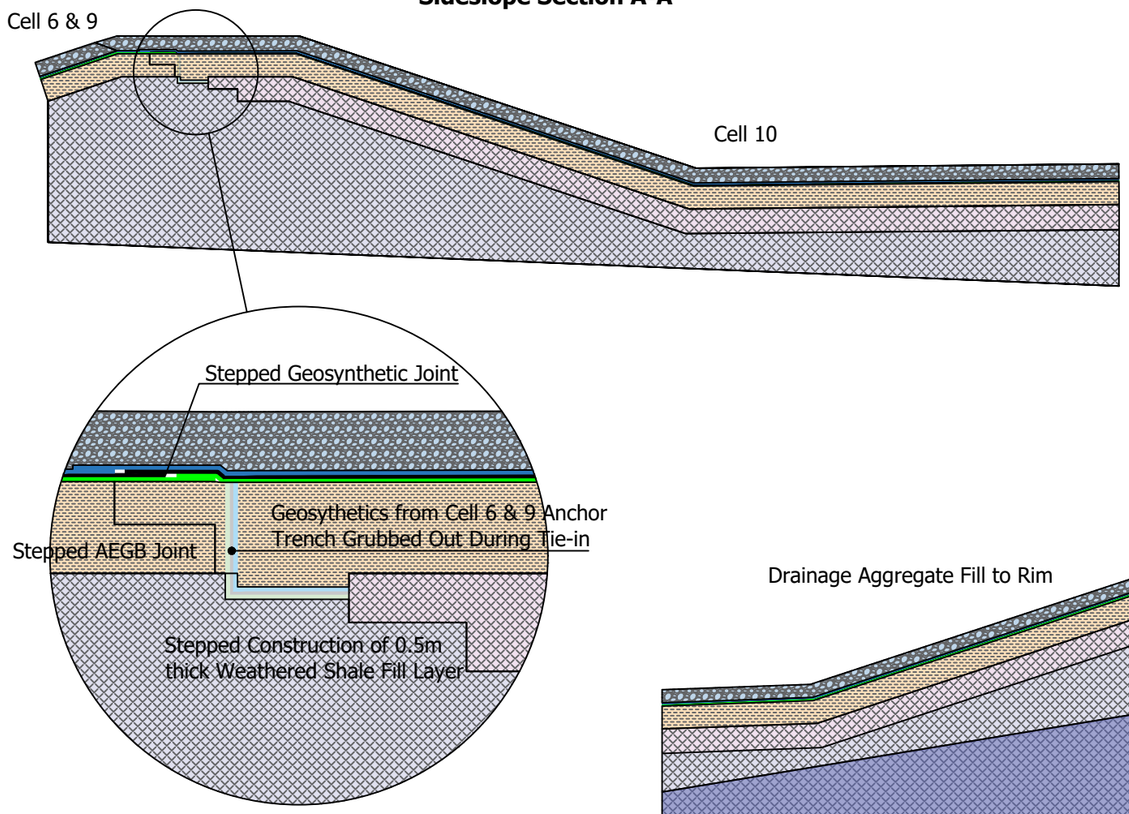
DRAWING NUMBER
2511/8

SCALE AT A3	DATE	DRAWN
1:1250	**02.25**	**KJT**

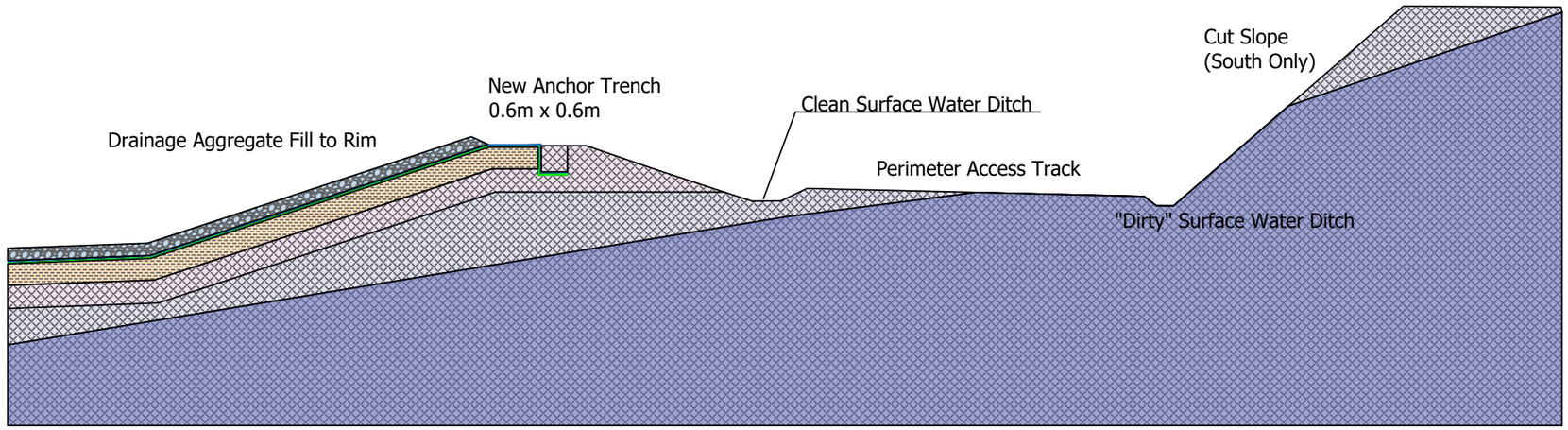
NOTE
Issued for NRW Consultation

GEO TECHNOLOGY

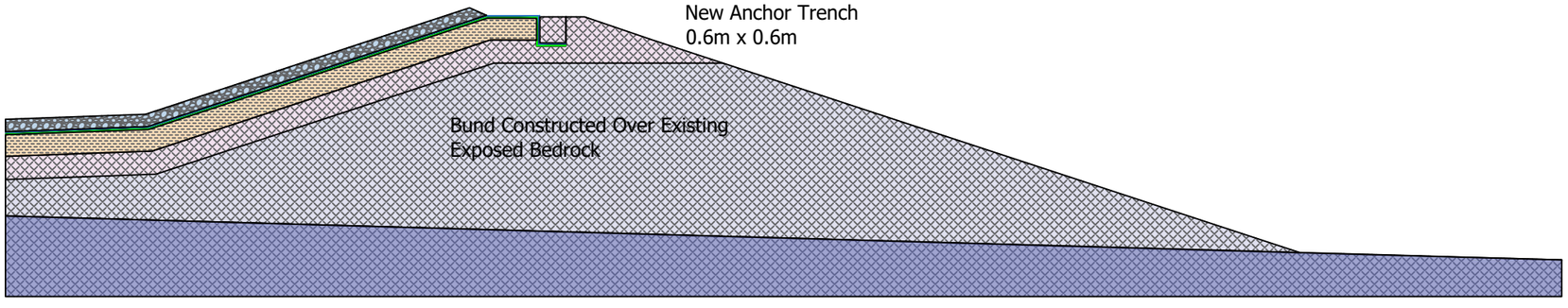
Sideslope Section A-A'



Inset Showing Stepped Joint Construction Detail



Sideslope Section C-C'



Sideslope Section B-B'

RML RESOURCES MANAGEMENT UK LTD

LEGEND
- In-situ Natural Ground (Slate Bedrock)
- Slate Derived Class 1 Fill
- Weathered Slate Class 1 Fill

NOTES
- Compacted Mineral Liner
- Aggregate Drainage Blanket

PROJECT: **Withyhedge Landfill Phase 2 Cell 10**

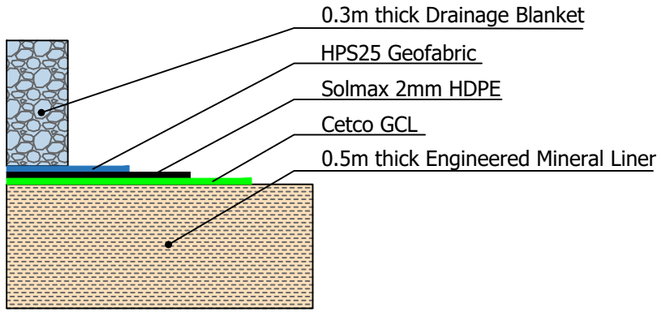
TITLE: **Sideslope Details**

DRAWING NUMBER: **2511/9**

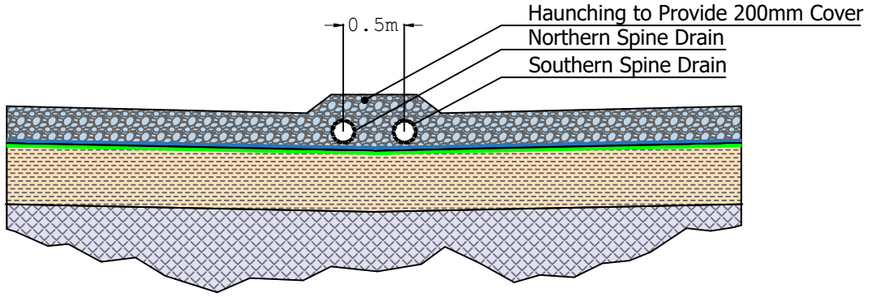
SCALE AT A3	DATE	DRAWN
NTS	**02.25**	**KJT**

NOTE: **Issued for NRW Consultation**

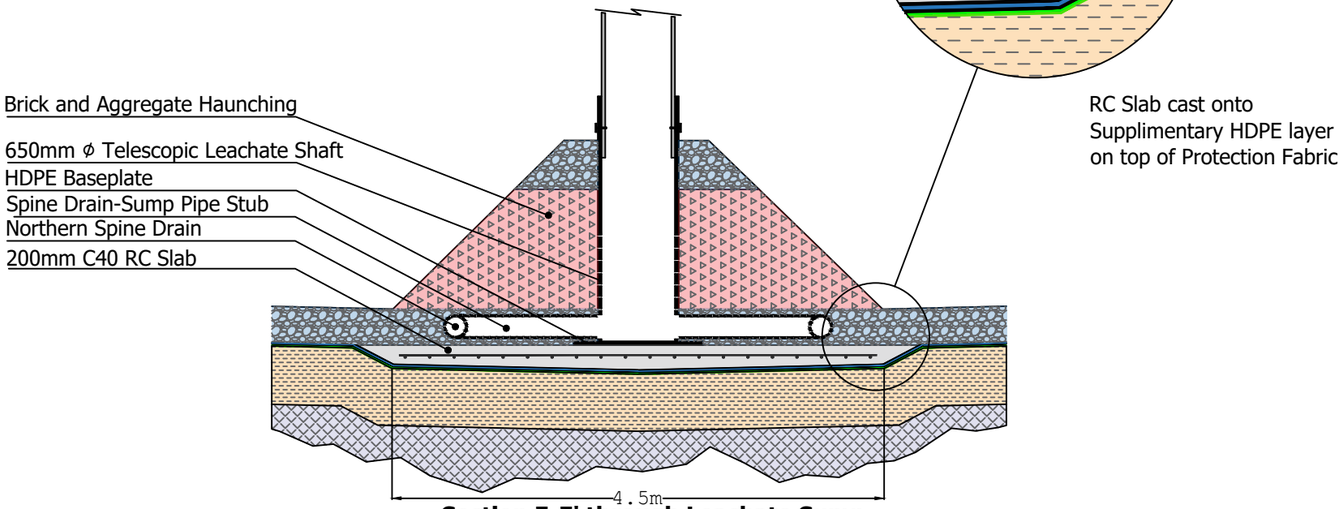
GEO TECHNOLOGY



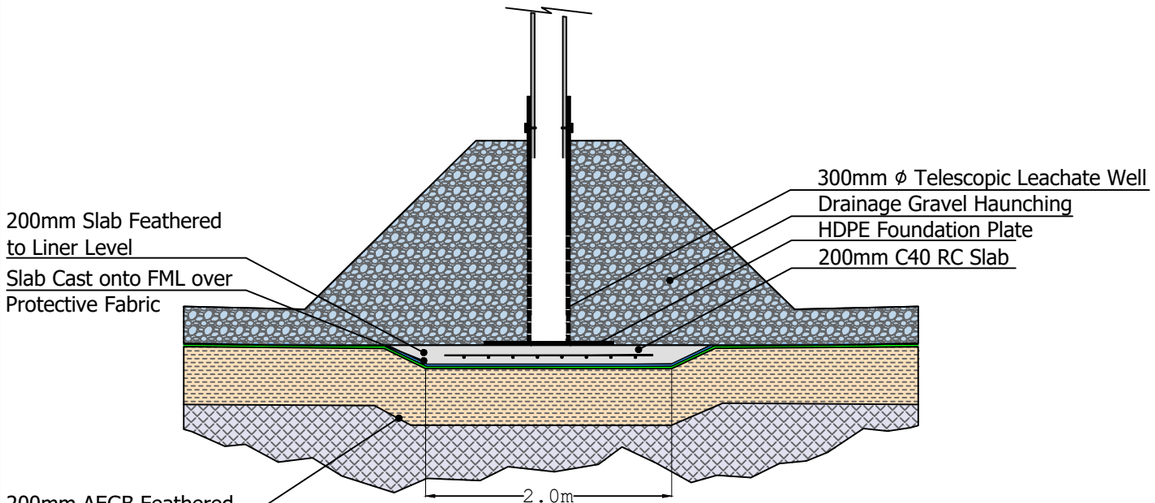
Lining Build-up



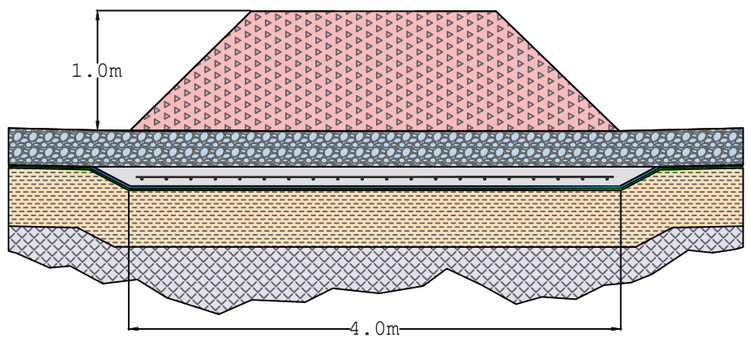
Section F-F' through Spine Drain



Section E-E' through Leachate Sump



Section G-G' through Monitoring Well



Section H-H' through Target Pad

RESOURCES MANAGEMENT UK LTD

LEGEND

- Site Won Compacted Fill to Formation
- Compacted Mineral Liner
- Reinforced Concrete

NOTES

- Aggregate Drainage Blanket
- Brick Target Layer

PROJECT: **Withyhedge Landfill Phase 2 Cell 10**

TITLE: **Construction Details**

DRAWING NUMBER: **2511/10**

SCALE AT A3	DATE	DRAWN
NTS	**02.25**	**KJT**

NOTE: **Issued for NRW Consultation**

GEO TECHNOLOGY

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WITHYHEDGE LANDFILL
PHASE 2, CELL 10

Construction Quality Assurance Plan for Basal Lining

Report Number 2511r2v1d0225

Appendix 3 Example CQA Forms

Daily Site Record Sheet CQA1

Site	Withyhedge Landfill Phase 2, Cell 9	Date	

CQA Staff				
Contractors				
Weather AM	Weather PM	Temp Max	Temp Min	Rainfall
Plant / Equipment	Hours of Operation	Comments		
Visitors				
Health and Safety				
Deliveries				
Work Undertaken				
Prepared by		Signed		

Delivered Materials Inventory

CQA3

Site	Withyhedge Landfill Phase 2, Cell 9

Date	Material	Manufacturer	Delivery Note	MQC Received?	MQC Pass?	Sample Number	Handle Store	Visual Check	Approved

Aggregate Delivery Record CQA4

Site	Withyhedge Landfill Phase 2, Cell 9	Material	

Date	Delivery Note / Ticket No.	Delivered (Tonnes)	Cumulative (Tonnes)

Daily Earthworks Record

CQA6

Site	**Withyhedge Landfill Phase 2, Cell 9**	**Material**	

Date	Location	Layer	Visually Satisfactory	Volume Placed m^3	Cumulative Volume m^3	Layer Thickness (mm)	No. of Passes	Approved	Non-Conformance No.	Comment

Mineral Liner In-Situ Testing and Sampling

CQA8

Site	Withyhedge Landfill Phase 2, Cell 9	Material	

Test Reference	Location Eastings	Location Northings	Layer	Test Type	Test Date	Sample No	Sample Type	Shear Strength kPa (HV)	Result 1	Result 2	Approved	Non-Con No

Mineral Liner Surface Condition Record

CQA9

Site	Withyhedge Landfill Phase 2, Cell 9	Surface		Material	

Date	Location	Total Area	1m Lath	3m Lath	Strength	Pass/Fail	Comment	Non-Con No

Acceptance Record CQA10

Site	Withyhedge Landfill Phase 2, Cell 9		Date	

Area Under Consideration

The subgrade for the geosynthetic elements has been prepared in accordance with the Specification and its surface has been inspected visually. Testing has confirmed that this part of the subgrade has an acceptably smooth finish and survey work has shown the surface has been prepared to the correct line and level. There is no evidence of soft spots, ponded water, ice, snow, frozen ground, peat, vegetation, stones, rocks or any protrusions.

Both the CQA Engineer and the Contractors Representative consider that the area is suitable for lining works to proceed and the Contractor accepts responsibility to maintain the subgrade in this condition until covered with lining materials.

The area of geosynthetic material has been visually inspected by the geomembrane installer and the CQA Engineer and is acceptable. All field and laboratory test results are complete, and the results are satisfactory.

Engineer		Signature	

Contractor		Signature	

Geosynthetic Materials Inventory

CQA11

Site	**Withyhedge Landfill Phase 2, Cell 9**	**Manufacturer & Material Type**	

Date	Batch No	Roll No	Length	Width	MQC Received?	MQC Pass?	Sample Number	Handle Store	Visual Check	Approved

Geosynthetic Panel Deployment

CQA12

Site	Withyhedge Landfill Phase 2, Cell 9	Material		Installer	

Date	Roll No	Panel No	Thickness L	Thickness R	Thickness F	Thickness B	Length	Width	Visual Check	Non-Con No

Geomembrane Seam Construction

CQA13

Site	Withyhedge Landfill Phase 2, Cell 9	Membrane		Installer	

Date	Seam No	Panel Nos	Length	Machine	Operator	DS Number	NDT Type	APT Start	APT Finish	Approved

Geosynthetic Repair Record

CQA14

Site	Withyhedge Landfill Phase 2, Cell 9	Material		Installer	

Date	Repair No	Location	Defect Type	Repair Type	Machine	Operator	NDT	Test Time	Pass/Fail	Approved

Non-Conformance/ Non-Compliance Record Sheet

CQA15

Site	Withyhedge Landfill Phase 2, Cell 9	Date	

Reference Number	
Material	
Location	
Date	
Details of Non-Conformance	
CQA Plan Reference	
Remedial Action Undertaken	
Approval for Incorporation into Works	
Signed	

CQA Summary and Checklist

CQA16

Site	Withyhedge Landfill Phase 2, Cell 9	Material	

No	CQA Activity-Reference as per Specification	Inspection or Test	Frequency of Test	Person Responsible	Type of Record	Completion		Comments
						% Complete	% Remaining	

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