BANGUS QUARRY LANDFILL DEVELOPMENT
BANGUS QUARRY, TUMBLONG, NSW

TECHNICAL SPECIFICATION
CELL 1 & 2 AND LEACHATE DAM CONSTRUCTION

Prepared for
MH Earthmoving Pty Ltd
150 Sheridan Street
(PO Box 227)
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Project Number ISA-161-18-19

Revision 0

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InSitu Advisory

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- This report has been prepared by **InSitu Advisory Pty Ltd** with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with the Client.
- Information reported herein is based on the interpretation of data received, which has been accepted in good faith as being accurate and valid.
- This report is for the exclusive use of MH Earthmoving and relevant statutory parties associated with the preparation of the EIS and approvals process.
- No warranties or guarantees are expressed or should be inferred by any third parties.
- This report may not be relied upon by other parties without written consent from InSitu Advisory Pty Ltd.

DOCUMENT CONTROL

Report	Status	Date	Prepared	Checked	Authorised
ISA-161-18-19	Revision 0	20 October 2019	Alan Dyer	Darren Herdman	Alan Dyer
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List of Abbreviations and Definitions

AHD	Australian Height Datum
CQA	Construction Quality Assurance
CQC	Construction Quality Control
DRS	Double Rough Sheet
ENM	Excavated Natural Material, defined in the NSW EPA excavated natural material exemption 2014 (http://www.epa.nsw.gov.au/resources/waste/rre14-excavated-natural-material.pdf)
EPA	Environment Protection Authority
GCL	Geosynthetic Clay Liner
HDPE	High Density Polyethylene
LCES	Leachate Collection and Extraction System
LEMP	Landfill Environmental Management Plan
m	Metres
MARV	Minimum Average Roll Value
MaxARV	Maximum Average Roll Value
NSW	New South Wales
RL	Reduced Level
TSS	Total Suspended Solids
VENM	Virgin Excavated Natural Material, as defined in Schedule 1 of the Protection of the Environment Operations Act 1997
WH&S	Work Health & Safety

Definitions

Construction Quality Assurance (CQA) Engineer	Supervising Engineer for the works, ensuring works are undertaken in accordance with the CQA Plan and Technical Specification
Construction Quality Assurance (CQA) Plan	NSW EPA approved document forming part of the Contract Documents, describing the construction quality assurance requirements for the Works
Contract	The contractual agreement between the Principal and Contractor
Contractor	The individual, partnership, corporation, joint venture, alliance, or other legal entity having a Contract with the Principal to perform the Work. It is likely that MHE will be the main Contractor for the works.

Contract Documents	The documents that form the contract. The written agreement between the Contractor and the Principal covering the Work.
CQA Engineer	Supervising Engineer for the works, ensuring works are undertaken in accordance with the CQA Plan and Technical Specification
Designer	The firm or organisation who has undertaken the design of the proposed Landfill works, in this instance InSitu Advisory Pty Ltd
Geosynthetic	Synthetic material (man-made plastic and fabric) used in geotechnical and construction applications
Geosynthetic Installer	Specialist firm subcontracted by the Contractor to complete the installation of geosynthetics including all field construction quality control activities, including (but not limited to) field seam testing.
Independent Testing Laboratory	The NATA accredited firm responsible for conducting all required laboratory tests.
Principal	MH Earthmoving Pty Ltd
Regulatory Authority	Authority responsible for licensing the works, in this instance the NSW EPA
Site	Bangus Quarry, Tumblong Reserve Road, Tumblong, NSW
Subcontractor	TBC (engaged by the Contractor)
Superintendent	Person(s) authorised by the Principal to manage and oversee the landfill construction works (the Superintendent may be the Principal or CQA Engineer) - TBC
Technical Specification	This document
Works	The whole of the work to be executed in accordance with the Contract, including variations provided for by the Contract, which by the Contract is to be handed over to the Principal
Works Area	As defined by the Contract Drawings

1 INTRODUCTION

1.1 General

MH Earthmoving Pty Ltd (MHE) has commissioned InSitu Advisory Pty Ltd (InSitu Advisory) to provide engineering design services for the construction of a general solid waste (non-putrescible) landfill development at Tumblong Quarry, Tumblong Reserve Road, Tumblong, NSW (the site). The proposed landfill development seeks to remediate the existing gravel pit which, after the proposed excavation to formation levels will be nearing the end of its useful life, by providing a waste disposal facility which will service Visy, a large major player in the resource recovery and recycling industry.

This Technical Specification has been prepared by InSitu Advisory Pty Ltd (InSitu Advisory) to detail the design requirements, construction processes and installation and testing quality control procedures that will be followed during the works. The Technical Specification must be read in conjunction with the CQA Plan and other Contract Documents.

This Technical Specification details the engineering requirements to allow MHE to achieve additional landfill void space in full accordance with the EPA Environmental Guidelines: Solid Waste Landfills, Second Edition, 2016.

This Technical Specification contains the technical requirements for materials and procedures to be implemented for the construction of the Landfill Works and leachate dam at the site and must be read in conjunction with the other Contract Documents. Where the Technical Specification and any other Contract Documents do not agree, the Contractor shall seek clarification from the Designer or Principal.

1.2 Site Location

The Site is identified as Lot 7004 of Deposited Plan 1028797 and Lot 7300 of Deposited Plan 1149008 and was designated as a quarry (Reserve 89508) in 1975. The Site is located within the Tumblong region within the Cootamundra-Gundagai Regional Council area. The Site is located on the gravel surfaced Tumblong Reserve Road, approximately 1.2 kilometres from its intersection with the Old Hume Highway. In turn, the sealed Old Hume Highway intersection with the current Hume Highway lies a further 2.3 kilometres away.

1.3 Outline Scope of Works

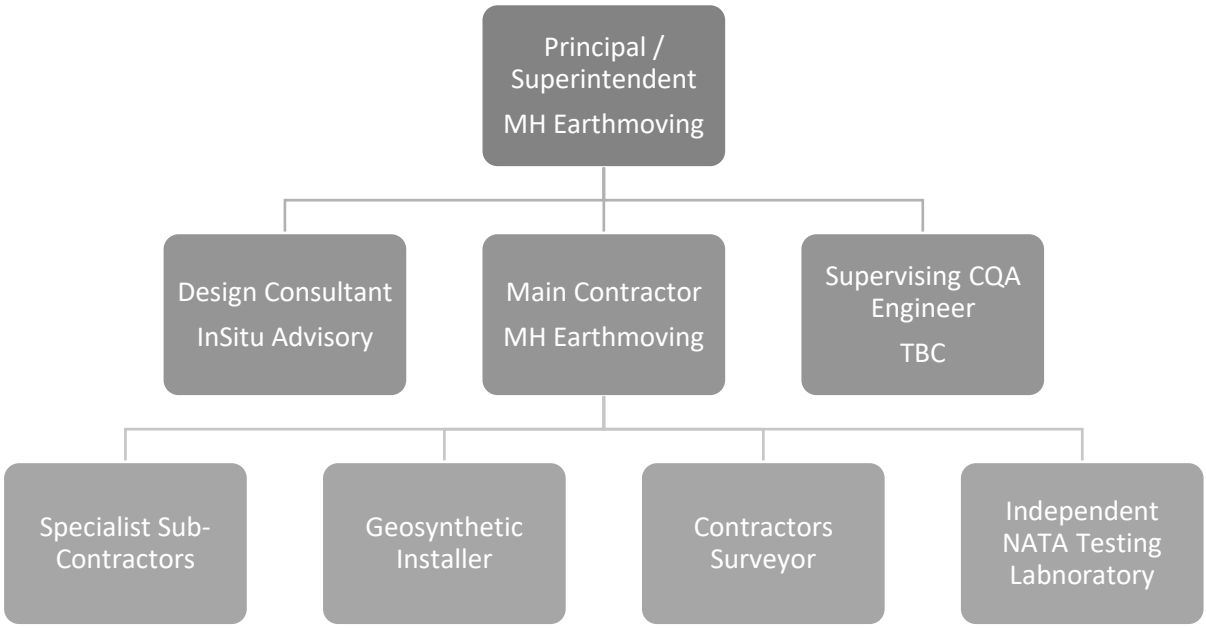
The proposed landfill works incorporate the following main elements of work:

- General site clearance including removal of minimal vegetation and hauling to locations shown on the drawings;
- Selective removal of existing subsoils and topsoils and placement in designated perimeter windrows/bunds for future reuse;
- General excavation of in-situ materials to achieve formation levels within Cells 1 & 2, the leachate dam and stormwater pond with generation of additional gravel resource for Council and site use;
- Haulage of excess and unsuitable materials to stockpile locations shown within the drawings;
- Placement of suitable compacted engineered clay-rich fill from within the quarry to achieve design sub-base and peripheral intercell bunds to subgrade levels;
- Supply and installation of Geosynthetic Clay Liner (GCL) on the landfill side slopes, bunds and landfill floor within Cells 1 & 2 and within the proposed leachate dam;
- Supply and installation of 2.0mm double rough sheet (DRS) geomembrane on the cell base, side slopes and adjoining intercell bunds, and within the proposed leachate dam;
- Installation of a suitable protection (cushion) geotextile above the geomembrane lined surfaces;
- Installation of 300mm minimum thickness suitable aggregate leachate drainage blanket;
- Supply and installation of leachate collection pipework, including 250mm and 150mm internal diameter perforated pipes and 400mm internal diameter leachate collection side slope risers;

- Supply installation of separation geotextile above granular leachate drainage blanket; and
- Construction of landfill access roads, hoppers etc.

1.4 Lines of Communication

The lines of communication for the Works are detailed below. The Supervising CQA Engineer shall be the main point of liaison between the Contractor and the Principal.



1.5 Responsibilities

1.5.1 Principal Responsibilities

MHE is the Principal for the project and assumes overall responsibility for the project.

The Principal is responsible for the following;

- Engaging a main Contractor;
- Engaging a Supervising CQA Engineer;
- Ensure compliance with environmental regulation, legislation, standards and codes;
- Obtaining all approvals and permits for construction activities;
- If necessary, inform the regulatory/planning authorities of any non-compliance; and
- Ensuring compliance with any existing site licence, planning condition etc.

1.5.2 Contractor Responsibilities

The Contractor is responsible for the following;

- Compliance with the Specification and CQA Plan;
- Site clearance and exploratory excavations to locate the limits of the existing infilled waste.
- The construction and testing of all elements described in this Specification.

- Works area management with regard to surface and groundwater management, dust suppression etc.
- Ensure compliance with environmental regulation, legislation, standards and codes;
- Assist the Principal in obtaining all approvals for construction activities;
- Maintain site records related to the implementation of the CQA Plan;
- Alert all contractor and subcontractor staff to the contents of the Specification and CQA Plan and ensure they comply with the requirements and commitments;
- Report any incidents to the Supervising CQA Engineer and Principal; and
- Thoroughly investigate any incidents and conduct corrective or preventative actions where necessary.

The Contractor shall supply all plant, materials (other than those earthworks materials made available by the Principal within the site) and incidentals required to carry out and complete the works associated with the landfill development work as shown on the Drawings and as outlined in this Contract Specification.

1.5.3 CQA Engineer Responsibilities

The CQA Engineer engaged directly and independently from the Contractor by the Principal. The CQA Engineer may also act as the Superintendent if nominated by the Principal.

The CQA Engineer shall be responsible for assessing the compliance of the completed Works with the Works Documents. Responsibilities are detailed within the CQA Plan.

The CQA Engineer shall have suitable experience of supervising all aspects of the works.

This Specification is intended to be referred to by the CQA Plan. The Contractor shall allow the CQA Engineer, the Superintendent and the Superintendent's representative's full access to the Works so that they may undertake their responsibilities in accordance with the CQA Plan.

1.6 Personnel and Relevant Experience

Prior to commencement of the Works, the Contractor shall provide a list of key personnel he proposes to employ together with a resume of their experience and qualifications to the Principal. The list of key personnel shall include the name of the full-time Contractor's Agent. The list will be accompanied with a chart showing the key personnel on the project and who / what they are responsible for.

The Contractor shall maintain an experienced management, supervisory and quality control team under the nominated project manager that is committed to achieving and maintaining the standards specified for the works.

The Contractor shall give or provide all necessary superintendence during the execution of the Works and as long thereafter as the Principal or CQA Engineer may consider necessary. Such superintendence shall be given by an experienced person having adequate knowledge of the operations to be carried out (including the methods and techniques required, the hazards likely to be encountered and the methods of preventing accidents) as may be requisite for the satisfactory construction of the Works. At all times during the contract the Contractor must have a trained First Aider present on site.

1.7 Adherence to the Discharge Consents and Site Rules Etc.

Prior to commencement of the Works, the Contractor and the CQA Engineer will attend a pre-contract meeting with the Principal, the Engineer and CQA Engineer to discuss the Works and to familiarise the Contractor with the potential hazards of the Works, Discharge Consents and the Site Rules, and current planning permissions etc.

1.8 Relevant Standards

Plant, materials and workmanship shall comply as a minimum with the requirements of current standards and Codes of Practice of the Standards Association of Australia (Standards Australia) as appropriate. All materials and workmanship not covered by a Standard shall be of such kind as is suitable for the environment and conditions under which the works are to be constructed.

1.9 Schedule of Figures

The following figures have been prepared and shall be read in conjunction with this Technical Specification:

Figure Number	Revision No.	Title
0	0	Cover Page and Drawing List
1	0	Site Location Plan
2	0	Existing Layout & Site Boundaries
3	0	Existing Site Survey
4	0	Proposed Landfill Subgrade Levels and Layout Plan
5	0	Engineered Sub-Base and Bunds Layout Plan
6	0	Proposed Engineered Geosynthetics Layout
7	0	Typical Sections and Construction Details
8	0	Proposed Leachate Drainage Blanket and Pipework Layout Plan
9	0	Leachate Drainage Construction Details
10	0	Phased Excavation Plan
11	0	Infrastructure Layout Plan
12	0	Leachate Dam & Infrastructure Layout Plan

1.10 Authorities

All work on this Contract shall be carried out in accordance with the requirements of all authorities having jurisdiction over the works.

1.11 Pre-Construction Approvals

1.11.1 Pre-Qualification of the Geosynthetic Installer

The Contractor shall provide a list detailing the level of experience and previous projects undertaken that are similar to this Specification by the proposed geosynthetic installer. For each example, the following information shall be provided:

- The name and purpose of the facility, its location, and the date of installation
- The name of the owner of the facility
- If requested, the name and telephone number of a reference contact at the facility who can discuss the project
- The type(s) of seaming, patching, and tacking equipment

The Contractor shall also provide:

- Certification that the Geosynthetic Installer's Field Crew Foreman has a minimum of 200 hectares of actual geosynthetic installation experience and a minimum of 100 hectares of supervisory experience for geosynthetic installation on a minimum of 10 different projects
- Certification that the Geosynthetic Installer's Seaming Foreman is an International Association of Geosynthetic Installer's Certified Welding Technician and has a minimum of 100 hectares of actual geosynthetic seaming experience and a minimum of 50 hectares of supervisory experience during the seaming of geosynthetic materials
- Certification that each individual on the Geosynthetic Installer's Seaming Crew has a minimum of 10 hectares of geosynthetic seaming experience and a minimum of 5 hectares of seaming experience with geosynthetics similar to this Specification. This condition may be relaxed at the discretion of the Superintendent to allow training of installation staff.

1.11.2 Pre-Qualification of the Contractor's Independent Testing Laboratory

The Contractor's Independent Testing Firms(s) shall be National Association Testing Authorities (NATA) accredited and proof of accreditation shall be maintained throughout the duration of the Works. Prior to construction, the Contractor shall provide NATA certification that the proposed laboratory is certified to undertake each specific test required.

The Contractor shall provide a letter stating that the proposed testing laboratory is independent and has no financial interest in the Contractor, the Geosynthetic Installer or any of the manufacturers/suppliers that are providing materials for the Works.

1.11.3 Works Program

The Contractor shall prepare a draft program for the Works. The program shall encompass all phases of the Works. The Contractor shall submit a draft of the program to the Principal / Superintendent for review and approval at least two weeks prior to construction. The Contractor shall not undertake any works on the site until approval for such is given by the Principal / Superintendent. The program shall include regular progress meetings with the Principal and CQA Supervising Engineer.

1.11.4 Contractors Construction Quality Control Plan

The Contractor shall prepare and implement a Construction Quality Control (CQC) Plan for duration the Works. The CQC Plan shall address all quality considerations detailed within in this Specification and the CQA Plan.

The CQC plan shall include as a minimum the following aspects: field testing, field verification, manufacturer's certifications and quality control testing from the manufacturing plant, to demonstrate that all aspects of the Works comply with this Specification and CQA Plan. The CQC plan shall also demonstrate how construction will occur and the methods by which the materials will be supplied, placed and tested to ensure compliance with this Specification.

The Principal may review and make suggested edits the Contractor's implementation of the CQC plan. The Contractor shall co-operate with all such auditing.

Works shall not commence until the CQC plan has been approved by the Superintendent / Principal.

1.12 Construction Quality Control

All construction quality control (CQC) testing shall be arranged by the Contractor and shall be carried out by the Contractor's Independent Testing Firm. The cost of CQC testing shall be borne by the Contractor. Copies of all test results shall be sent to the Superintendent as soon as available but in any event within two days of becoming available. The minimum testing frequencies shall be as nominated within this Specification.

At any stage throughout the Works, the Superintendent may arrange for independent testing and/or surveying to be carried out (costs borne by the Principal). If that testing reveals that any works are found to be non-compliant with the requirements of the Specification, CQA Plan and the Contract Drawings, the Contractor shall undertake rectification of the non-compliant items and conduct re-testing in accordance with this Specification. All costs of undertaking such rectification work and re-testing shall be borne by the Contractor.

1.13 Materials

The Contractor shall be responsible for the sourcing, delivery, storage, preparation, handling and installation of all materials, except as modified in individual sections of this Specification.

Where a specification issued by the Australian Standards is current and is appropriate, goods and materials used in the execution of these works shall be in accordance with the specification; however, the Contractor shall name all sources of materials to be supplied to site for approval of the Superintendent. Any material condemned or rejected by the CQA Engineer will be removed immediately from the site. All materials will be stored and transported in such a manner as to preserve their quality and integrity.

Material and installation specifications are included within this Specification for each material type.

1.14 Plant and Equipment

The Contractor shall use plant of suitable and appropriate capacity to carry out the work in accordance with the Specification. Each item of plant will be maintained and operated in a safe manner. Plant operators are to be trained and certified by an approved body for the plant they are operating. The Contractor will consider the potential safety hazards of the proposed works and adapt plant and vehicles accordingly.

1.15 Existing Services

The locations of all existing services within the area of the works shall be identified, through consultation with the Principal, by the Contractor prior to commencement of works. Such services shall include, but not necessarily limited to buried conduits (telecommunications and gas), water supply mains, overhead electricity cables, leachate collection pipework, landfill gas infrastructure. There may be a need to either relocate or redirect a number of existing services to complete the works as specified, which shall be arranged by the Superintendent.

The Contractor shall make every effort to avoid damage or disturbance to any existing services or structures located within the site, particularly existing groundwater monitoring bores. The Contractor shall erect and maintain temporary barriers, boarding's etc., and shall alter their work practices, as may be required for the protection of such installations.

1.16 Land Available for the Contractors Use

The Contractor shall have full possession of the Landfill Works area and stockpiles as defined within the Drawings. During construction works, the movement of traffic associated with excavation, site clearance, ground preparation, and supply of resources to and from the landfill site will require to be monitored at all times so as not to interfere with other vehicles accessing the site. The Contractor shall liaise with the Principal to obtain information regarding any other Contractors working on the site, and shall consider this when programming the works.

Vehicle movement with regards to excavation and transport of excavated materials shall be limited to the areas of excavation and stockpile locations. The whole of the site and any ancillary works shall be left in a clean and tidy condition. Damage to land or property on access routes and in the vicinity of the working area shall be made good.

A suitable area for temporary site office accommodation and storage of material shall be agreed with the Principal. The Contractor shall seek the approval of the Principal for any other areas to be used for stockpiling materials or access onto the working area.

1.17 Existing Site Topography

The land rises from approximately 267m AHD on the western boundary up to 287m AHD in the north-east corner of the site. The existing quarry floor level ranges principally between 268m and 269m AHD, with the top of the cut quarry slope ranging from approximately 279m AHD on the southern flank, approximately 284m AHD on the eastern flank and approximately 271m AHD on the northern flank.

Figure No. 3 shows the current contoured ground levels undertaken by T.J. Hinchcliffe & Associates Pty Ltd, (February 2019) provided by the Principal.

1.18 Hydrology and Drainage

The topographical profile of the area around the site determines the behaviour of the local runoff hydrology and drainage. Surface water flow appears to be in a westerly direction from the higher land towards the lower levels. Crude stormwater ditches are evident around the perimeter of the quarry that lead to culverts under the Tumblong Reserve Road, to a neighbouring water storage dam.

1.19 Independent Quality Assurance Supervision

The Works will be supervised by an independent CQA Engineer appointed by the Principal. This CQA Engineer may also function as the Superintendent or Superintendents Representative under the Conditions of Contract, unless otherwise informed in writing.

1.20 Setting Out and Surveys

Available temporary reference benchmarks are currently available and indicated on the Drawings or are available from the Principal. The Contractor shall establish whatever survey control that is necessary for set out of the works, and shall ensure that all available survey reference stations are suitably protected from disturbance and damage at all times during the works duration.

Construction surveys required to be carried out by the Contractor are highlighted in Section 1.23 below.

1.21 Existing and Final Ground Levels

The Contractor will be given a suitable ordnance or temporary benchmark on or near the site to which all levels shall be referred. The Contractor will be required to agree original ground levels with the Principal prior to commencement of site works.

The Contractor should verify for himself the accuracy of all survey data. The agreed original ground levels shall provide a basis for measurement purposes.

Figure No. 3 shows the current contoured ground levels undertaken by T.J Hinchcliffe & Associates Pty Ltd of Wagga Wagga.

If the Contractor's survey of original ground levels differs to the ground levels shown in Figure No 3, the Contractor's survey shall be sent to the Designer to ensure the cell design is still applicable.

The Contractor shall carry out construction surveys to determine ground elevations and coordinates at each of the following stages of earthworks and during liner construction and at other times as may be necessary to measure quantities for payment purposes:

- prior to commencing earthworks
- on completion of general cut for landfill Cells 1, 2, the leachate dam and the stormwater pond;
- on completion of general filling (including placement of engineered sub-base and bunds);
- on completion of GCL deployment for the landfill cells and the leachate dam;
- on completion of HDPE geomembrane installation i.e. intersections of seams and panels, patches & repairs for the landfill cells and the leachate dam;
- on completion of protection geotextile installation i.e. intersections of seams and panels, patches & repairs etc (providing levels as the means of determining aggregate drainage blanket thickness bottom level)

- on completion of aggregate drainage blanket & leachate extraction system (pipework) installation
- on completion of all stockpiles and fill areas external to the Landfill area.

The Contractor shall provide sufficient notice of the intention to undertake a survey to enable the CQA Engineer to conduct a joint survey or check the Contractor's survey.

The Contractor shall provide an isopachyte of layer thickness for the basal subgrade and the leachate aggregate blanket thickness, required for submission within the CQA Validation reporting to the NSW EPA.

Surveys of the works area shall be undertaken using a fixed 10m x 10m check grid, or layout as agreed with the CQA Engineer. Surveys will be used as a basis to prove layer thicknesses and fixed positioning to ensure the Works are in accordance with the Specification and Drawings.

The Contractor shall forward a paper and electronic copy of the "raw" survey within 5 days of undertaking the survey to the CQA Engineer. The electronic survey data submitted, shall be an AutoCAD DXF or DWG file. Proceeding with installation of an overlying layer prior to confirmation that the thickness requirements of the proceeding layer have been attained as calculated by survey, is at the Contractors own risk.

1.22 Tolerance Limits

The tolerance limits for the Works shall be as follows:

- positions in plan shall be within 75mm of the true positions as shown on or calculated from the Drawings.
- slopes and base grades shall be sensibly plane and within 1% of the gradient shown on the Drawings.
- prepared subgrade, compacted clay liner (top of engineered fill liner) and granular drainage blanket in the base of Landfill shall be within -0/+30mm of the required elevation.
- heights of bunds shall be no less than those indicated on the Drawings and shall not exceed them by more than 100mm. The crests shall be sensibly plane with no obvious corrugations or low areas where water may pond.
- depths and thicknesses of compacted clay liner and granular drainage blanket shall not be less than the dimensions shown on the Drawings.

1.23 As-Built Drawing Information

Contractor shall survey and plot accurately all work carried and installed. This information shall be prepared in a properly drafted, scaled and detailed form to the satisfaction of the Superintendent to enable preparation of 'as-built' drawings for the works. The Contractor shall provide one (1) set of Works as Executed Drawings certified by a Registered Surveyor

The Contractor shall produce final 'as built' drawings as detailed as follows:

- prior to commencing earthworks;
- on completion of general cut;
- on completion of general filling (including placement of engineered sub-base, perimeter and intercell bunds);
- on completion of GCL deployment for landfill Cells 1, 2, the leachate dam ;
- on completion of 2.0mm HDPE geomembrane installation i.e. as built panel layout drawings, showing panel numbers, intersections of seams and panels, seam numbers, defect/repair locations, and destructive sample locations for landfill Cells 1, 2, the leachate dam;
- on completion of the leachate collection and removal system installation, including top of drainage stone levels, all pipework and installation of the leachate extraction risers/chambers, specifically the base levels; and

- on completion of all stockpiles and fill areas external to the proposed landfill area.

All survey documentation shall be incorporated into the CQA Validation Report.

The Contractor shall submit this information to the Superintendent in the following forms:

- Two sets of A3 sized printed plans
- Emailed or memory stick of data containing the information in DXF format.

1.24 Stockpiles and Spoil Heaps

The location and management of material stockpiles and spoil heaps shall be discussed and agreed with the Principal prior to commencement of the works. The height of any stockpile or spoil heap shall under no circumstances exceed 6m above the original ground level.

Stockpiles must be sealed to prevent water ingress and graded to ensure surface water run-off at the end of every working day or on cessation of use/import whichever is earlier. Excavation from stockpiles shall be carried out in such a manner that the stockpiles are maintained in a stable condition at all times. It is the Contractor's responsibility to ensure that stockpiles do not adversely affect the stability of any other excavation at the site.

1.25 Safe Working Method Statements

The Contractor shall produce Safe Working Method Statements (SWMS) for each element of the construction works, especially when they interact with site operations. SWMS shall detail how the works are to be undertaken in a safe manner, in order to meet the Specification, WHS requirements, site rules, EPL and regulatory requirements. The SWMS shall detail how the work is to be carried out and the plant and equipment proposed.

The Contractors attention is drawn to the fact that all SWMS are to be reviewed by the Superintendent/Principal, the Engineer CQA, and possibly NSW EPA. SWMS shall be issued to the Superintendent at least one week prior to commencing the specific task to allow time for distribution to the other stakeholders for receiving comment as to their suitability.

The Superintendent may reject the submitted work method statement if, in the opinion of the Superintendent, the statement does not comply with the Specification or any other Contract Documents provided to the Contractor prior to or during construction. Where a work method statement is rejected the Contractor shall revise and resubmit the statement. No work addressed by the work method statement shall be undertaken by the Contractor until the work method statement is approved by the Superintendent.

Acceptance by the Superintendent of a proposed work method statement in no way reduces the Contractor's liability to achieve the requirements described in this Specification

The Contractor's attention is drawn to the presence of landfill gas within the works area. Gas levels will be monitored by the Contractor to demonstrate to the CQA Engineer that levels are sufficiently low to permit working.

The Contractors staff will be inducted by the Superintendent prior to carrying out any work on site.

1.26 Hold Points

A hold point is a defined position in the Works beyond which work shall not proceed without mandatory verification and acceptance by the Superintendent. It is the Contractor's responsibility to ensure that all obligations are fulfilled in regards to the hold points within the Contract. The Contractor shall give the Superintendent a minimum two (2) days' notice prior to the required inspection

The hold point relates to the condition of a surface or installed material, the Contractor shall verify that the completed surface has achieved full conformance with the Contract Documents. Hold points may be released for part of the Works area only, as determined by the Superintendent, so that the Works can be completed in a sequenced manner. The Superintendent's approval of the completed items is required prior to the release of each hold point.

Hold points are as follows:

- Completion of excavation to approved formation levels
- Completion of engineered sub-base and bunds to required levels
- Completion of GCL installation (rolling hold point)
- Completion of HDPE geomembrane (rolling hold point)
- Completion of protection geotextile installation
- Completion of initial electrical leak detection survey in Cells 1 & 2 and the leachate dam
- Completion of leachate drainage aggregate and pipework installation
- Completion of final electrical leak detection survey
- Completion of separator geotextile installation

1.27 Inclement Weather

When weather conditions are such that the quality of the Works may be impaired or the conditions of the materials impaired then the Works will be stopped with the agreement of the Superintendent or CQA Engineer. Inclement weather may comprise high winds, rain, excessive temperatures or a combination of the above.

Following adverse weather conditions, any standing water on the surface of the works shall be removed at the earliest opportunity.

Where, in the opinion of the Superintendent or CQA Engineer, any works carried out in inclement weather conditions that have been adversely affected, these works shall be removed and made good.

Earthworks placement operations following inclement weather conditions shall not proceed without prior approval of the CQA Engineer.

1.28 Erosion and Sediment Control

The Contractor shall draft and implement their own erosion and sediment control plan (ESCP) for the Works with consideration to this Specification, EIS, planning and EPA approvals and the Drawings. In preparing the ESCP, the Contractor shall reference the following:

- Landcom (2004) Managing Urban Stormwater: Soils and Construction – Volume 1 (4th Ed.), informally referred to as the “Blue Book”.
- NSW EPA (2009) Managing Urban Stormwater: Soils and Construction – Volume 2B, Waste Landfills.

The ESCP shall identify all erosion and sediment control measures the Contractor shall implement during the Works (including staging). The plan shall identify monitoring the Contractor shall undertake to ensure the Contractor complies with the surface water release criteria at the site. The plan shall be submitted to the Superintendent for review and approval at least five (5) working days prior to commencement of the Works. The Contractor may not commence working until the ESCP is approved by the Superintendent/ Principal.

The Contractor shall provide all temporary erosion and sediment control measures necessary to protect the areas within and immediately adjacent to the Works Area from negative impacts.

The installation and subsequent removal of temporary erosion and sediment control works shall be the responsibility of the Contractor. The extent of removal of the temporary works shall be confirmed by the Contractor with the Superintendent before the end of the Contract.

Materials used for the temporary erosion and sediment control works shall be removed from the Works area or otherwise disposed of by the Contractor to the satisfaction of the Superintendent. Maintenance of permanent control measures shall be the responsibility of the Contractor until such a time determined by the Principal or up to the date of de-mobilisation or contract completion.

1.29 Locational Considerations

The design of landfill has considered the locational considerations of the NSW EPA Environmental Guidelines 2016 with regard to an inappropriate area for landfilling is within 40m of a permanent or intermittent water body etc, see EIS document submit for approval.

2 EXCAVATION AND FILLING

2.1 Definitions

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

a) "Suitable fill material" - shall comprise of all that which is in accordance with the Contract for use in the Works, and deemed by the CQA Engineer to be suitable. "Suitable fill material" is sub divided into two categories 'general fill material' (site derived fill) and 'imported clay material'.

b) "Unsuitable material" shall mean material other than suitable materials and shall include:

i. Peat, material from swamps, marshes and bogs

ii. Materials contaminated through past site usage which may contain toxic substances or soluble compounds harmful to water supply or agriculture

iii. Logs, stumps and perishable material

iv. Material susceptible to combustion

v. Materials containing fire ant infestation/s

vi. Any industrial, commercial or domestic waste

vii. Actual or potential acid sulphate soils (ASS)

viii. Materials having a moisture content greater than the maximum or less than the minimum permitted for such materials in the Contract unless otherwise permitted by the CQA Engineer and Engineer

ix. Clay of liquid limit exceeding 80% and/or plasticity index less than 10% or exceeding 50%

x. Stones with a minimum dimension greater than 0.125m

xi. Shear strength <50 kPa.

Materials of Class vi) above if otherwise suitable shall be classified as suitable when wetted or dried sufficiently as appropriate.

c) Rock shall be defined as hard strata found in ledges or masses in its original naturally occurring position which in normal excavation would have to be loosened by blasting or pneumatic rock tools or if by hand using wedges and sledge hammer or strata requiring the use of diamond or tungsten carbide bits when drilled.

General construction fill will be sourced from on-site suitable clay, test data for the clay fill is presented within Appendix B.

General construction fill may also be sourced from excavations within the site, as nominated by the Superintendent as long as it meets the requirements of Section 2.1.

2.2 Required Standards

The relevant Australian standards are detailed as follows:

- AS1289 Methods of testing soils for engineering purposes
- AS1289.2.1.1 Determination of the moisture content of a soil - oven drying method
- AS1289.3.1.1 Soil classification tests - Calculation of the plasticity index of a soil
- AS1289.3.6.1 Soil classification tests - Determination of the particle size distribution of a soil Standard method of analysis by sieving
- AS1289.3.6.3 Soil classification tests - Determination of the particle size distribution of a soil Standard method of fine analysis using a hydrometer

- AS1289.3.8.1 Soil classification tests - Dispersion - Determination of Emerson class number of a soil
- AS1289.5.1.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort
- AS1289.5.6.1 Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material
- AS1289.5.7.1 Soil compaction and density tests - Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method)
- AS1289.5.8.1 Soil compaction and density tests - Determination of field density and field moisture content of a soil using a nuclear surface moisture density gauge
- AS1289.6.7.2 Determination of the permeability of a soil - Falling head method for a remoulded specimen
- AS1289.6.7.3 Determination of the permeability of a soil - Constant head method using a flexible wall permeameter
- AS1726 Geotechnical site investigations
- AS2868 Classification of machinery for earthmoving, construction, surface mining and agricultural purposes
- AS3798 Guidelines on earthworks for commercial and residential developments
- AS4419 Soil for landscaping and garden use

2.3 Suitable Equipment

All earthworks shall be undertaken using conventional earthmoving equipment in good working order and well maintained. Equipment shall be and operated in accordance with the equipment manufacturer's instructions.

2.4 Site Clearance

General site clearance (clearing and grubbing) is required to strip surface vegetation from the landfill and ponds footprint. General vegetation includes grass, shrubs, live trees and dead trees either standing or fallen. The Contractor shall liaise with the Principal as to where storage of the cleared vegetation shall be placed, this will likely be placed by the Contractor at the green waste processing area within the site.

All natural landscape features, including natural rock outcrops, natural vegetation, soil and watercourses are to remain undisturbed except where affected by the Works.

Any materials cleared that is not vegetation, shall be segregated and hauled to the landfill facility, after consultation with the Principal.

2.5 General Excavation

Bulk excavation is required to achieve firm formation levels (see Figure 4 for indicative formation levels) prior to the placement of suitable clay fill materials needed to construct a 200mm sub-base grade and bunds to levels shown on Figure 5. Excavation is required within the footprint of the proposed landfill to firm material (>50kPa) suitable for the placement of engineered clay fill subgrade and compacted clay liner.

The Contractors attention is drawn to the fact that ground conditions within the current quarry area are fairly consistent and are likely to comprise the following:

- Banded siltstone and quartzite rock;
- Sandy, silty loam overburden.

Recent borehole investigations undertaken by D.M McMahon Pty Ltd in February 2019 (details presented in Appendix A) within the floor of the proposed Landfill have provided the following information:

- Borehole 1 (589132E 6113443N) Siltstone with low or no plasticity between 0.0m – 21.6m.
- Borehole 2 (589104E 6113494N) Siltstone with low or no plasticity between 0.0m – 21.6m.
- Borehole 3 (589049E 6113449N) Siltstone with low or no plasticity between 0.0m – 21.6m.
- Borehole 4 (589097E 6113425N) Clay and siltstone with low or no plasticity between 0.0m – 21.6m.
- Borehole 5 (589094E 6113458N) Clay and siltstone with low or no plasticity between 0.0m – 21.6m.

Where the excavation reveals a combination of suitable and unsuitable material the Contractor shall, unless otherwise agreed with the CQA Engineer, carry out the excavation in such a manner that the materials are excavated separately for use in the Permanent Works without contamination by mixing of materials. All materials shall be immediately transported to a stockpile location agreed with the Principal or placed directly within the works.

The Contractor shall be deemed to have satisfied himself as to the nature of the deposits on site and have included within their rates for the selective excavation of each material.

The Contractor must review the accompanying CQA Plan to ensure they are familiar with the requirements of the CQA Engineer and their responsibilities and duties.

The Contractor shall inform the CQA Engineer without delay, should unsuitable material, as defined in Section 2.1 be encountered within the excavation.

Excavation slopes shall be finished in conformance with the lines and grades shown on the Drawings or as re-determined by the Superintendent on the basis of site inspection and investigation during the works. All loose material shall be removed from the works area.

Temporary excavated faces shall be left in a safe, stable condition with fencing or barrier tape.

Excavation of anchor trenches are required to be completed in accordance with the drawings. Excavated materials, if suitable, shall be temporarily placed for subsequent reinstatement and compaction.

Excavation surfaces shall be rolled, where applicable, to provide a smooth surface, free from debris, roots, angular or sharp rocks and allow free drainage between shifts. The formation should provide a firm unyielding foundation sufficient to permit the movement of vehicles without causing rutting or other deleterious effects. It shall have no sharp or abrupt changes in grade, and shall be free from areas of soft material.

All soft spots identified by the CQA Engineer or Superintendent following the rolling of the excavation levels shall be removed and re-filled with compacted suitable general fill and placed in accordance with Sections 3.6 and 3.7.

Although unlikely, localised or perched groundwater water and/or surface water seepages may enter the excavation from the surrounding ground; therefore, there may be a requirement to pump this water to allow earthworks to proceed. Temporary watercourses, ditches, drains, pumping or other means of maintaining the Works free from water, shall be required and provided by the Contractor.

On no account will any unauthorised discharge be permitted to leave the site without prior consent of the Principal, who may consult the NSW EPA. The Contractor shall adhere to all existing site discharge consents.

The Contractor shall ensure low ground pressure equipment is used when compaction is required over piping, geosynthetics, leachate drainage aggregate or similar.

The Contractor shall ensure that all stockpiles are rolled / sealed at the end of each shift or at the onset of rain.

3 COMPACTED CLAY SUB-BASE AND BUNDS

3.1 Materials Requirements

Compacted engineered clay fill placed above the trimmed subgrade shall comprise cohesive materials of medium to high plasticity, which produces a competent fill when compacted to Specification requirements.

Suitable materials for the compacted clay liner shall:

- Comprise cohesive materials of medium to high plasticity;
- Be relatively free of organic material;
- Have the following properties:
    - Liquid Limit < 80%;
    - Plasticity Index > 15%;
    - Maximum particle size of 20mm;
    - > 98 % passing 19mm sieve;
    - > 30 % passing 0.075mm sieve;
    - > 20 % passing 0.002mm sieve;
    - Emerson class > 3; and
    - Organic content < 2%.
    - Cation Exchange Capacity (CEC) > 10 mEq/100 gm

It is anticipated that materials for the engineered sub-base and bunds shall be sourced from site-won clay or as nominated by the Superintendent. Details of the site-won material considered suitable for use are provided in **Appendix B**.

Haulage of suitable materials to the areas of placement shall only proceed when sufficient spreading and compaction plant is operating at the place of deposition. There shall be minimum delay between placement and compaction to minimise moisture loss or absorption.

Prior to filling with imported fill, the ground surface shall be scarified or bladed until it is uniform and free from uneven features which may prevent uniform placement and compaction. The scarified ground surface shall then be brought to appropriate moisture content, mixed as required and compacted.

All fill shall be placed, spread, mixed, moisture conditioned and compacted in accordance with this Specification and CQA Plan.

Where imported fill is to be placed against *insitu* site clays, the surface of the existing *insitu* material shall be cleared of any soft material (<50kPa) and any loose debris or deleterious materials to the satisfaction of the CQA Engineer. Each lift of imported fill placed shall be benched into the *insitu* material to ensure that an adequate key is achieved.

Fill materials shall be placed subject to the relevant clauses of the Specification, with due regard to moisture conditioning and compaction, as necessary, to produce a fill material possessing the fill quality and performance, as specified.

If material to be placed is in or attains a condition (e.g. as a result of inclement weather), such that it cannot be spread or compacted in compliance with the Specification requirements, or then one of the following courses of action shall be undertaken:

- the affected material shall be removed and discarded and/or stored until it attains a suitable condition; or
- the material shall be treated by wetting or being allowed to dry as appropriate.

Fill slopes steeper than 20% gradient shall be overfilled as necessary and trimmed back with an item of plant equipped with a smooth blade to ensure that all fill in the slope is adequately compacted.

Unless otherwise specified, fill material shall be placed with a maximum compacted lift thickness of 200mm. Each lift shall be spread evenly and thoroughly mixed to obtain a uniform condition within each placed lift.

Where work is interrupted by rain, fill operations shall not be resumed until observations and field tests by the Contractor indicate that the moisture content and density of the in-place fill materials and/or materials intended for placement are within the limits identified in this Specification. This requirement does not preclude the Contractor from disking or aerating excessively wet areas to enhance drying.

The CQA Engineer shall arrange for quality control tests to be carried out on fill materials to ensure the Specification requirements are being met by the Contractor. The Contractor shall to permit control testing to be carried out within the works area.

The final filled general formation shall be rolled to provide a clean even, firm foundation.

3.2 Field Trial Pad

Prior to construction of the landfill compacted clay liner, a field trial shall be carried out to prove that the Contractor's proposed construction methodology and plant will meet the Specification requirements.

The trial should be carried out on the same trimmed formation on which the liner will be constructed, in an area not less than 20m x 20m. Where significantly different gradients are incorporated in the liner design, the field trials must be carried out at gradients that reflect the different field conditions. The trial pad shall generally include a trial on the base and sidewalls or bunds. Where sidewalls are of a similar gradient to intercell bunds and where the formation conditions are similar, then only one (i.e. sidewall or bund) trial pad shall be undertaken in addition to the base.

The material used in the field trial shall be placed in loose layers of thickness no greater than 250mm to achieve a maximum compacted layer thickness of 200mm using a padfoot or other suitable type of roller, as appropriate.

The layer shall be compacted initially with '6, 8 and 10' passes of the compaction plant and tested for each compaction regime under the direction of the CQA Engineer to determine the most effective method of achieving the required Specification.

On completion of testing and sampling of the first layer, the trial panel shall be scarified to a minimum depth of 50mm and the next layer shall be placed, compacted, sampled and tested. This process shall be repeated until the trial panel has been constructed to the required depth.

The purpose of the Field Trials shall be to provide field verification of the moisture/density relationships as determined from the source evaluation testing.

The following aspects of the compacted imported clay liner layer installation shall be evaluated

- method of selective excavation/processing of the imported clay liner layer material;
- material handling and placement requirements;
- compaction equipment and procedures;
- number of passes of equipment necessary to achieve the required results;
- confirmation of in-situ moisture density criteria and establishment of correction;
- factors for use of a nuclear density gauge;
- materials testing to confirm previous characterisation results; and
- adequacy of inter layer bonding.

The testing regime shall comprise the following tests per layer of the trial panel:

- Two No. dry density/moisture content relationship using either nuclear density gauge or core cutter method, for each specified number of passes made by the compaction plant;
- Two No. hand shear vane readings (19mm vane)
- One sample for dry density/ moisture content relationship (4.5kg rammer).

- The following testing shall be taken from the layer with the optimum number of compaction passes:
- One bulk sample for laboratory classification testing which would include Plasticity Index, Particle Density and Particle Size Distribution.
- One Triaxial Undrained Shear Strength (U38 method)

For establishing the in situ moisture density correction factors for use of a nuclear density gauge the Contractor shall take a minimum of 3 core cutter samples (or sand replacements to AS 1289:5.3.1) adjacent to three nuclear density gauge tests on each lift of the trial. An in-situ calibration shall be used to calibrate the NDG for field use. The results obtained from the in-situ calibration may show a scatter of results, and it is important to carry out a sufficient number of tests to provide a reliable calibration factor. A minimum of five discrete testing locations on a trial area is required. The trial area shall be formed using the plant and equipment that will be employed during the works.

On completion of the field trial, the Contractor shall excavate a section through the trial panel to demonstrate the adequacy of the inter layer boundary resulting from the contractors proposed methodology.

Where the results demonstrate that the methodology and plant used for the compaction trial achieve the required Specification, works may proceed with placement of the imported compacted clay fill and the trial panel may be incorporated into the permanent works. If the results of the trial prove unsuccessful, the placement methodology and/or compaction plant shall be changed and a further trial carried out to assess the revisions. This process shall continue until the CQA Engineer is satisfied that the proposed plant and methodology will produce satisfactory results. If the compaction trial is carried out within the area of the Works, any non-conforming material shall be removed prior to imported compacted clay liner construction.

Prior to sampling of the field trial, the final rolled surface is trimmed to remove any pad foot indentations and to provide a clean unyielding surface. Samples are then taken from this trimmed surface. Photographs shall be taken during the trial pad construction and during the post placement inspections.

3.3 Placement Procedures and Compaction Requirements

Placement and compaction of fill material is to be undertaken in accordance with Australian Standard AS 3798-2007 *Guidelines on earthworks for commercial and residential developments.*

The compacted clay liner shall be constructed using the plant and methodology determined by the field trial. The compaction method shall not be changed without further trials to demonstrate the suitability of the revised method.

The Contractor shall submit a fully resourced method statement detailing the plant, equipment and manpower proposed, to include compaction techniques proposed for the works

Prior to compaction each discrete (loose) lift will be visually inspected by the Contractor and all unsuitable material as detailed in Section 3.1 shall be removed.

If material to be placed is in or attains a condition (e.g. as a result of inclement weather), such that it cannot be placed or compacted in compliance with the Specification then one of the following courses of action shall be undertaken.

i) The affected material shall be removed and discarded and/or stored until it attains a suitable conditions, or

ii) The material shall be treated by wetting or being allowed to dry as appropriate.

Haulage of suitable materials to the areas of placement shall only proceed when sufficient spreading and compaction plant is operating at the place of deposition. There shall be minimum delay between placement and compaction.

The Contractor should be aware that if the material in its natural state is drier than its plastic limit or optimum moisture content, conditioning of the material by water addition and thorough mixing may be required.. Under no circumstances should clods greater than 125mm across be placed; if present, large clods must be broken down prior to placement.

General Construction Fill shall be compacted to a dry density of not less than 98% of standard maximum dry density (AS 1289.5.1.1). Measured moisture contents from compacted General Construction Fill shall fall within the range of -2% to +2% of optimum moisture content (AS 1289.5.1.1), but must also be wet of plastic limit to avoid desiccation.

All perforations made in the imported compacted clay liner for testing or sampling purposes shall be backfilled with bentonite or clay to the approval of the CQA Engineer. If clay is used, the material shall be manually re-compacted using a suitable hand-held rammer.

A vibratory pad-foot roller or other suitable compaction plant approved by the CQA Engineer should be used for construction of the compacted clay fill installation. If a smooth drum roller is used, the smooth surface is to be scarified to a depth of 30mm before the next successive lift of fill is placed.

No earthmoving or other plant which could damage the compacted material shall be allowed onto the surface of the material following satisfactory compaction.

The surface shall be sealed (by smooth drum rolling) at the end of each day to minimise the penetration of water, with erosion protection measures provided and drainage systems (permanent and temporary) maintained.

Tolerances for compacted fill for base and side walls are +50mm, -0mm.

3.4 Construction Quality Control Testing

The Superintendent or the CQA Engineer will arrange for control tests to be carried out on imported compacted clay liner materials as are considered necessary to satisfy himself that the Contractor is using appropriate materials for the purpose of the works and is working in accordance with the Specification. The Contractor shall interrupt his fill operations, as necessary, to permit control testing to be carried out.

Tests shall be conducted by a NATA registered laboratory generally in accordance with the standards referenced below, or otherwise as determined to be appropriate.

The Contractor shall undertake the set of compliance tests detailed in Table 1 of the Technical Specification. Furthermore, the contractor shall take appropriate testing of the imported fill material, either at source or after importation to site to prove that the material consistently meets the requirements of Technical Specification section 3.1.

Additional testing may be required, exceeding the frequency given below, if in the opinion of the CQA Engineer, any deficiency is suspected. Test sample locations shall be nominated by the CQA Engineer in consultation with the Contractor.

The CQA Engineer shall highlight to the Contractor the extent of work rejected due to non-conforming test results based on the area represented by the non-conforming test results.

For the information of the Contractor, the following tests will be carried out.

Table 1 CQC Testing Requirements for Compacted Clay Fill Material

Test	Standard	Minimum Test Frequency*
Dry Density	AS 1289.5.1.1 AS 1289.5.7.1 or AS 1289:5.8.1	1 per 500m³ placed
Moisture Content	AS1289:5.1.1 or AS1289.5.7.1	1 per 1000m³ placed
Atterberg Limits	AS1289.3.2.1	1 per 1000m³ placed

Particle Density	AS1289.3.6.1	1 per 1000m³ placed
Particle Size Distribution to clay fraction	AS1289.3.6.1	1 per 1000m³ placed

*Compacted in place

CQC testing for all earthworks shall be carried out by the Contractor's independent NATA accredited testing laboratory who shall supply reports identifying the material type, the Specification requirements, and associated test results.

As part of the Contractors CQC measures, the Contractor shall keep a detailed log of insitu field testing undertaken on the fill to include the following aspects, test number, test location in respect to the works area, description of the fill material, compacted lift tested, density ratio, moisture content and method of testing tin accordance with AS1289 Methods of Testing Soils for Engineering Purposes (Standards Australia, various dates) or equivalent methods in other recognised quality standards. The Contractor shall annotate on a plan the test locations which shall be shared and compared with the CQA Engineer.

Retests shall be undertaken on areas of the works where CQC tests do not meet the Specification requirements, retests shall be clearly identified in the detailed log.

All perforations made in the compacted clay fill for testing or sampling purposes shall be backfilled with hydrated bentonite or clay to the approval of the CQA Engineer. If clay is used, the material shall be manually re-compacted using a suitable hand-held rammer.

The in situ field dry density shall be measured using a nuclear density gauge (NDG) sand replacement, or core cutter method. If a nuclear density gauge is used the readings will be corrected using the factors established during the field trial. In addition nuclear density readings will be further verified by core cutters at a minimum of 1 per 5 NDG readings. The corrected dry density and moisture shall be immediately plotted to assess the specific criteria required for the works.

3.5 NDG Site Testing Procedure

The following stages will be completed when performing an NDG test at each test location:

- tests shall be carried out on a level area free from loose material and standing water. If a sheep's-foot roller has been used then a dozer, excavator or smooth roller shall be used to prepare the test area. The test area will not be prepared using a tamping method to flatten out the surface, as this will affect the compaction characteristics of the material being measured;
- using the levelling plate as a guide, the metal pin shall be driven into the ground using a hammer to the required depth for the test. The steel pin will be removed by pulling out vertically and twisting to remove any suction the ground may be inserting on the pin. The pin shall not be hammered from side to side to loosen it in the ground, as this will disturb the test hole. With the plate still in place above the hole the pin shall be used to score around the perimeter of the plate. The plates are made to the same dimensions as the base of the gauge, by marking the plate on the ground the gauge can be positioned with the probe directly above the hole ready for testing;
- the probe shall be lowered into the test hole to the required depth. The gauge shall be positioned so that the probe is in contact with the side of the guide hole nearest to the body of the gauge;
- a minimum test time of 1 minute shall be used. Three readings shall be taken at each location, moving the body of the gauge by 180° for each individual reading. If the three results differ by more than 5% of each other then a fourth reading shall be taken. The bulk density and moisture content for each reading shall be recorded, averaged and converted using the relevant correction factors; and
- due to the inherent scatter of NDG test results a density core shall be taken from every fifth NDG test location or one every day, whichever is greater. The density core shall be tested for bulk density and moisture content in accordance with AS1289:2.1.1 (determination of moisture content) and AS 1289:5.8.1 (determination of density: linear measurement method). The results

shall be assessed against the NDG reading, plotted on the calibration curve and correction factors amended accordingly. All results shall be included in the CQA Validation Report.

The undisturbed samples for laboratory permeability testing shall be taken by the Contractor from the finished imported compacted clay liner layer under the supervision of the CQA Engineer. The samples shall be taken by placing a thin walled sample tube, upright on the completed material and jacking down the tube vertically and steadily. Upon excavation the sample shall be sealed labelled and sent to an approved accredited laboratory for determination of permeability.

As part of the Construction Quality Assurance programme the CQA Engineer must verify the imported clay layer thickness. Thicknesses shall be calculated from survey data undertaken. The Contractor shall set up a grid at 10m spacing over the area of the imported clay liner layer, to enable accurate calculation of layer thickness. The Contractor should ensure all survey data is passed to the CQA Engineer within 5 days of undertaking the survey.

3.6 Remedial Works

Should remedial works to non-confirming test results, surface desiccation etc be necessary, the Contractor shall scarify the compacted fill layer to the required layer depth and subsequently re-compact in accordance with the Specification. The CQA Engineer shall observe the remedial works and take necessary notes and records for inclusion within the CQA Validation report. Any remedial works carried out to the compacted clay fill subgrade level shall be carried out to the full satisfaction of the CQA Engineer.

If the CQC testing demonstrates that the compaction requirements are not being achieved, the Contractor must carry out the following remedial works at their own expense:

- Undertake additional works on the layer as necessary such that subsequent testing of the layer meets the required compaction requirement. Measures may include moisture conditioning or aeration of placed materials, additional passes of the compacting plant or other measures as deemed suitable by the CQA Engineer.
- Remove the part of the layer demonstrated to have not met the required compaction requirement and replace it to the satisfaction of the CQA Engineer.

Following a thorough re-working of a non-conforming area, retesting to the requirements set out in Table 1 shall be performed by the Contractor to evaluate whether the re-worked area meets the requirements of the Specification. The Contractor shall undertake all necessary remedial work, including retesting, to reinstate the work to the requirements of this Specification.

The CQA Engineer shall record all locations/areas of non-compliance together with remedial actions taken and shall not permit placement of a subsequent layer on the area until compliance is achieved.

Any soft spots identified in the formation and subgrade surface shall be excavated to the satisfaction of the CQA Engineer and backfilled with suitable fill material placed and compacted in accordance with this Specification.

3.7 Subgrade Preparation

The final subgrade shall have no sudden sharp or abrupt changes in grade and shall be free from areas excessively softened by high water content. The final subgrade shall be rolled to provide a clean even, firm foundation sufficient to permit the movement of vehicles without causing rutting or other deleterious effects. The Contractor shall seek approval from the CQA Engineer as to the adequacy of finished rolled surface.

The prepared subgrade shall be proof rolled by a mechanical self-propelled smooth drum roller (or equivalent) in the presence of the CQA Engineer to assess the soundness and suitability of the subgrade. Proof rolling shall be conducted on the full length and width of the subgrade. A final proof roll shall be conducted over the finished surface prior to acceptance by the CQA Engineer.

To show conformance with the requirements of the Specification, during final proof rolling of the prepared subgrade the surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability.

Should evidence of localised groundwater seepage be present, site remediation works shall be undertaken. This work shall typically involve excavating out any granular layer carrying water locally to the formation surface and replaced by engineered clay fill. Should any groundwater presence be more than localised, a groundwater relief drain shall be installed in the area which will channel the water to the collection sump and extraction riser (see Section 3). Any groundwater extraction riser would be temporary until waste was placed to equalise the hydraulic head and eliminate basal heave.

The trimmed compacted clay fill subgrade should be protected from damage due to sunlight, inclement weather and subsequent erosion. The surface of the compacted clay fill can be irreversibly deteriorated by the effects of desiccation cracking. Compacted clay fill exposed for more than 7 days before placement of overlying GCL and HDPE geomembrane materials should be covered and suitably protected to reduce the likelihood of the clay fill surface from drying out.

On completion, the compacted clay fill subgrade shall be surveyed to verify that it has been installed to the correct thickness and at the correct grades and falls.

The top layer of the reworked clay shall be finished as necessary to produce an even and stable surface, with the maximum permissible stone or object dimension being be 20mm. Any stones or objects greater than the permissible dimensions shall be removed from the final surface to the satisfaction of the CQA Engineer.

The subgrade shall be rolled and compacted such that in any event it provides a firm unyielding foundation sufficient to permit the movement of vehicles and welding equipment over the subgrade without causing rutting or other deleterious effects. The subgrade shall have no sudden sharp or abrupt changes in grade which exceed +/-10mm over a 1000mm distance and shall be free from areas excessively softened by high water content. The subgrade shall be free from track and roller marks.

The Contractor should not prepare excessive areas of compacted clay liner layer prior to GCL and HDPE geomembrane deployment. The compacted clay fill subgrade surface should be prepared such that there is minimum time between placement and geomembrane deployment. Any remedial works to repair previously prepared areas of regulatory layer will be at the Contractors expense.

The Contractor shall protect the surface from desiccation, flooding and freezing where appropriate. Protection will be at the discretion of the CQA Engineer. Protection may be in the form of a temporary thin plastic cover to be removed prior to liner installation. Surfaces containing desiccation cracks (greater than 25mm) or exhibiting swelling, heaving or other similar conditions shall be replaced or reworked by the Contractor.

The Contractor should be aware that to achieve the requirements as detailed in this section manual rock picking may be required.

3.8 Inclement Weather

Inclement weather conditions may include rain, high winds or excessive heat as indicated by the CQA Engineer or Superintendent on site.

No fill materials shall be placed, spread or compacted during inclement weather conditions if, in the opinion of the CQA Engineer, trafficking over compacted or uncompacted material would prove detrimental to the construction surfaces and works. Any such trafficking damage caused by the Contractor shall be repaired in accordance with the Specification at the Contractor's expense.

Following inclement weather conditions, any standing water must be removed prior to recommencement of works. If instructed by the CQA Engineer, the Contractor shall remove to spoil heaps any material rendered unsuitable. Earthworks placement operations following inclement weather conditions shall not proceed without the prior approval of the CQA Engineer.

3.9 As-Built Survey

An as-built survey is required after the clay filling stage in order to ensure the engineered clay liner and subgrade have been constructed to the correct level and position and also to ensure the proposed Landfill meets the requirements of

- the NSW EPA Guidelines 2016, Section 1.1 which states *'this primary barrier system should include the following components - a compacted sub-base 200 millimetres thick to provide a firm, stable, smooth surface of high bearing strength on which to install the liner'*

The thickness of the completed compacted clay fill shall be determined by a level survey grid, the following data shall be collected:

- for the base of Landfill, data shall be collected from points on a survey grid with node points no greater than 10m apart
- for sidewalls or batters data shall be collected from points on a survey grid with node points no greater than 5m apart
- for linear features or change in gradient (breaks of slope) 5m data points are required or at intervals to sufficiently represent the surface
- for all batters or sidewalls the minimum data points surveyed shall be top, bottom and middle of a batter of regular gradient
- over deepening features e.g. sumps / recesses for concrete target pads, to be surveyed at top and bottom of corners, change in gradient and low point
- tie-ins to previous liners must be surveyed to accurately reflect the work undertaken
- anchor trenches to be surveyed at the top of the front crest and the centreline of the base of the excavation.

If the results of the surveys and isopachyte of fill thickness indicates that the compacted clay fill does not achieve the requisite 200mm for the subgrade thickness, additional clay fill shall be placed and compacted in accordance with this Specification and the area(s) re-surveyed until the requisite thickness is achieved. Any additional clay fill that is required should not be placed in less than a 250mm layer. Isopachyte of clay thickness or representative cross sections on the side slopes at 20m intervals should be drawn to demonstrate thickness achieved.

3.10 Sign Off

The CQA Engineer shall be solely responsible for the satisfactory completion of all CQA testing activities in accordance with this Specification and the CQA Plan. The site clearance, soils separation and bulk earthworks shall be undertaken to the satisfaction of the Superintendent or the CQA Engineer. The Contractor shall retain ownership and responsibility for the subgrade until final acceptance of the subgrade by the CQA Engineer or Superintendent.

The subgrade shall be accepted by the CQA Engineer/Superintendent when all of the following conditions are met:

- CQC test results showing compliance with the requirements of this Specification have been provided by the Contractor to the CQA Engineer and approved.
- Details of all defects identified and repairs performed have been provided by the Contractor to the CQA Engineer and approved.
- The Contractor has submitted the required as-built surveys of the completed subgrade showing conformance with the required thicknesses and position, the Drawings, within the allowable tolerances, and this has been approved by the CQA Engineer.
- The CQA Engineer has provided the Principal with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

3.11 Construction Details

The compacted clay fill sub-base layer is to be constructed over the subgrade levels of Cells 1 & 2 and the proposed leachate dam in accordance with the Construction Drawings. Placement and compaction of fill material is to be undertaken in accordance with Australian Standard AS 3798-2007 *Guidelines on earthworks for commercial and residential developments.*

Specific requirements are as follows:

- The material shall be placed in loose layers such that when compacted, each layer does not exceed 250 mm thickness (or 150 mm for backfill within anchor trenches:
- Each layer is to be compacted to a dry density of at least 98 % of Standard Maximum Dry Density, with moisture content within the range of -2% to + 2 % of Optimum Moisture Content.
- Dry density and moisture content are to be confirmed via Control Testing.
- The finished compacted clay fill sub-base must have a minimum thickness of 200 mm measured at right angles to the slope as shown on the Construction Drawings.
- Bunds shall be constructed to the dimensions and grades shown in the construction drawings.

Prior to compaction, each discrete lift will be visually inspected by the Contractor and all unsuitable materials shall be removed.

Anchor trenches shall be compacted back to the same compaction and moisture content requirements as the sub-base and bund original construction requirements.

Should connections be required between adjacent lift layers, existing edges/faces will be trimmed back to remove any desiccated material such that the material exposed in the face complies with this Specification. The compacted clay liner material to be placed will be benched into the existing face/edge such that no continuous alignment of the vertical joints occur (see Construction Drawings).

A tapering clay fillet is required on the junction between the southern and eastern side slopes that thickens as the fillet descends the side wall. The fillet is required to eliminate a step in the side wall that would otherwise be there after the construction of the compacted clay liner in the base and lower side slope. The fillet removes the step between the side slope and the compacted clay liner in the base of the cell, allowing the HDPE side riser to lay flush on the side slope from top to bottom without any deviation (see construction details).

In heavily trafficked areas, such as access ramps into Landfill for the deployment of GCL, HDPE, protection geotextiles and placement of leachate drainage aggregate, temporary soil thickness should be at least 1000mm over the geosynthetics.

3.12 Landfill Access Road

The existing access road on the northern boundary of the proposed landfill is to be maintained to provide access to the proposed site infrastructure and parking area. Part of the eastern end of the existing access road will be joined to an internal site haul ramp out of the proposed cell that will be used to haul overburden materials to the adjacent land area (see Figures 2 and 10).

The gradient of the access road and ramp shall be suitable for truck access, under consideration of vehicle traction under full load.

4 GEOSYNTHETIC CLAY LINER

4.1 General

Geosynthetic Clay Liner (GCL) shall be handled, installed and tested in accordance with Appendix E of the Siting, design, operation and rehabilitation of landfills, VIC EPA BPEM documentation dated October 2014.

The GCL will be laid directly upon the prepared sub-grade and will extend over the whole of the Landfill area indicated on the Drawings.

In accordance with the NSW EPA Environmental Guidelines: Solid Waste Landfills, Second Edition 2016 (NSW EPA Guidelines 2016), GCL's used as alternatives to compacted clay should:

- consist of a thin layer of bentonite 'sandwiched' between layers of geotextiles with a hydraulic conductivity less than 5 x 10–11 metres/second
- be reinforced (i.e. the geotextile layers are bonded by needle punching or stitching to enhance the internal shear strength of the geosynthetic clay liner compared with that of unreinforced products)
- have adequate strength, flexibility and durability to maintain performance over the entire life of the landfill (including the operating and post-closure periods)
- meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications; see GRI-GCL3 (Geosynthetic Research Institute, 2010)
- be made from bentonite that has been formulated for landfill applications; the bentonite should meet the specifications in Table 2 below (in accordance with NSW EPA Guidelines 2016).

Table 2 Minimum Bentonite Specification

Property	Range or Value
Montmorillonite content	>70 wt%
Carbonate content*	<1 to 2 wt%
Bentonite form	Natural Na-bentonite or >80 wt % sodium as activated bentonite
Particle size	Powdered (e.g. 80% passing 75-micron sieve) or Granulated (e.g. <1% passing 75-micron sieve)
Cation exchange capacity	≥70 meq/100 g (or cmol/kg)
Free swell index	≥24 cm3/2 g

Note: * Carbonate here implies calcite, calcium carbonate or other soluble or partially soluble carbonate minerals.
Source: NSW EPA Environmental Guidelines: Solid Waste Landfills 2016)

The GCL shall be new and comprise a layer of bentonite distributed over a highly porous reinforcing layer, sandwiched between woven and non-woven geotextile material. The GCL manufacturer shall prove that the rolls delivered to site comply with the CQA testing requirements outlined within Table 2 above. Manufacturers test certificates shall be provided to the CQA Engineer to prove each rolls suitability and compliance prior to rolls being incorporated into the works.

4.2 Manufacturing Quality Control

As stated within the NSW EPA Guidelines 2016, manufacturing quality control details should be received from the manufacturer or supplier for all geosynthetic materials delivered to the site. This includes factory test results, certifications and material warranties. It also includes quality control details in relation to the raw materials (such as resins, bentonite, polymers and fibres) supplied to manufacture the geosynthetic materials.

The source of geotextile polymers must be identified, and it must be confirmed that the polymer has previously been demonstrated as suitable for use on landfill sites.

The manufacturing quality control details should show that the geosynthetic materials satisfy the requirements of the relevant specifications published by the Geosynthetic Research Institute (Folsom, Pennsylvania, USA) from time to time, or in equivalent recognised industry standard specifications. Relevant specifications are listed in section 1 of the EPA Guidelines 2016.

The Contractor shall submit to the Superintendent a copy of the following information prior to the installation of the GCL:

- The origin (suppliers name) and identification of the bentonite used for production of the GCL;
- A specification for the GCL which contains all properties contained in this specification;
- 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 specification;
- Copies of dated Quality Control information provided by the geotextile manufacturer;
- Written certification that the minimum values given in the specification are guaranteed by the 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. As a minimum, results shall be given for the properties listed in within Table 2 above.

Any GCL proposed by the contractor must meet the requirements of the NSW EPA Guidelines 2016.

Separate certificates shall be provided for tests conducted at a lesser frequency than 1 per roll. These certificates shall relate to the delivered rolls of material. The documentation shall be provided prior to installation of any material. Should any of the certificates indicate that the material properties do not meet with the acceptance criteria outlined in within Table 1 of NSW EPA Guidelines 2016 the CQA Engineer or Superintendent may reject the relevant roll(s).

4.3 Independent Conformance Testing

As soon as practicable after delivery of the GCL material to the site, the CQA Engineer shall select the rolls of GCL from which conformance samples are to be taken. The Contractor shall cut a sample 1 metre wide across the entire width of the roll, after the first lap has been discarded, from each of the rolls identified. The Contractor shall submit the samples for conformance testing in accordance with NSW EPA Guidelines 2016 Table 10 (repeated in Table 3) to an independent NATA accredited geosynthetic testing laboratory for the tests required.

In accordance with the NSW EPA Guidelines 2016 general requirements apply, as detailed below:

- Test results must be passed by the Construction Quality Assurance engineer before deployment of the geosynthetic material.
- All testing must be performed on samples taken from the geosynthetic rolls to be used for the works, with all sampling overseen by the Construction Quality Assurance engineer.
- All laboratory tests should be performed in a third-party, independent, accredited geosynthetics laboratory.

- Delivery of samples to the laboratory should be organised by the Construction Quality Assurance engineer, not the contractor. A suitable chain of custody procedure should be implemented.
- Test results should be sent directly from the laboratory to the Construction Quality Assurance engineer.
- The specified frequencies assume that all rolls are from a single continuous manufacturing run. The frequencies should be applied to each continuous manufacturing run producing the rolls to be used in the project.
- In the tables, 'ASTM methods' refers to standard test methods published by ASTM International (West Conshohocken, Pennsylvania, USA).
- The Construction Quality Assurance engineer should use his or her judgment as to whether independent conformance testing additional to the testing stipulated by the designer is required in particular circumstances during construction.
- If a sample records a non-conforming test result, it may be retested. If it passes this retest, both results should be provided in the laboratory report. If the retest produces a non-conforming result, the contractor should remove and replace all rolls between the sampled roll and the nearest conforming rolls either side (on the basis of the production order of the rolls). The contractor may, by testing and verification of these intermediate rolls, reduce the range of rolls to be removed in this way. Such additional testing should be for the full range of specified tests, not just the test or property that yielded a non-conforming result. Any replacement material should undergo the specified independent conformance testing.

Table 3 CQA Testing Requirements for Geosynthetic Clay Liners

Property	Standard	Frequency
GCL (geosynthetic clay liner) mass per unit area	ASTM D5993	1 test per 2500 m_2, including the first and last rolls (based on production order): minimum of two tests
Bentonite mass per unit area	ASTM D5993	1 test per 1250 m_2, including the first and last rolls (based on production order): minimum of two tests
Peel strength	ASTM D6496	1 test per 1250 m_2, including the first and last rolls (based on production order): minimum of two tests
Tensile properties (machine direction)	ASTM D6768	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
CBR (California bearing ratio) burst strength	AS 3706.4	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Fluid loss	ASTM D5891	1 test per 1250 m_2, including the first and last rolls (based on production order): minimum of two tests
Swell index	ASTM D5890	1 test per 2500 m_2, including the first and last rolls (based on production order): minimum of two tests
Cation exchange capacity	Methylene blue method	1 test per 2500 m_2, including the first and last rolls (based on production order): minimum of two tests
Permeability	ASTM D5887 or ASTM D6766	1 test per 10,000 m_2, including the first and last rolls (based on production order): minimum of two tests
Montmorillonite content and carbonate content	CSIRO x-ray diffraction	1 test per 10,000 m_2, including the first and last rolls (based on production order): minimum of two tests

Conformance sampling shall be undertaken at the frequency shown in Table 3 or for every change in batch numbers, whichever is the greater.

4.4 Delivery, Handling and Storage

Each GCL roll should be delivered with an identifying unique roll number, the manufacturer's name, product name and type, batch number, date of manufacture and physical dimensions. Any protection coatings shall not be removed until the material is ready to be incorporated into the works.

The GCL shall be delivered, handled and stored in accordance with the manufacturer's recommendations taking care to protect the material from damage and contamination. Geosynthetic materials should be stored to protect them from weather and other damage until installation. In particular, geosynthetic clay rolls should be kept dry.

The GCL shall be stored on a level, dry area at a location to be agreed on site and will not be stacked more than 2 rolls high with no materials being placed on top of the GCL. The storage area shall also be firm, clean and rolled flat to avoid damage to the GCL.

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, ultraviolet light etc until completion of the works.

The Contractor and CQA Engineer shall examine all rolls on delivery for damage in transportation and shall record the details of any damage together with the relevant manufacturer's reference numbers for each roll. Damaged rolls shall be set aside until the extent of damage and determination as to whether to reject the material can be determined.

A copy of the manufacturer's recommendations for storage and installation shall be provided to the CQA Engineer for their information.

4.5 Regulating Layer Surface Inspection

The surface of the trimmed subgrade layer must be inspected to ensure that there is a uniform surface free from protrudencies, sharp objects or any other materials that in the opinion of the CQA Engineer may cause damage to the overlying GCL.

Once the surface is deemed acceptable a Sub-grade Acceptance Sheet shall be completed and signed by both parties. Deployment of the GCL shall not take place until a subgrade acceptance sheet has been signed for the specific area to be lined.

4.6 Installation

GCL shall be installed within Cells 1 & 2 as well as within the proposed leachate dam as detailed within the drawings.

The GCL shall be installed in accordance with the manufacturer's recommendations, either manually or by approved suitable plant and equipment, so as to not cause damage to the GCL or disturbance to the trimmed subgrade layer. Installation of a geosynthetic layer should not start until the CQA Engineer has accepted the independent conformance test results for that material. Also, the Engineer must have passed the underlying layer as part of the hold point.

A copy of the manufacturer's recommendations shall be provided to the Superintendent for his information. Except in emergencies, plant will not track directly on to the installed GCL.

The Contractor shall provide a proposed panel layout plan prior to commencement of the works for acceptance by the Superintendent. A panel layout should be prepared before the installation of each geosynthetic layer; it should show the proposed arrangement of panels, including penetrations and connections and the proposed direction of working.

The GCL should be deployed in panels normal to the contours of the slope (i.e. directly down slope) in accordance with details on the Drawings, and should be in accordance with good practice and the manufacturer's instructions.

Geosynthetic layers should not be installed in wet weather or windy conditions and should not be left exposed for any length of time.

GCL panels shall be deployed with a minimum overlap of 300mm between panels or 500mm on end-of-roll overlapped seams and the overlapped joints shall be joined by sodium bentonite granules at a minimum rate of 0.5kg per metre of lap to ensure sealing between panels unless the material is impregnated.

Each panel shall be visually inspected by the CQA Engineer to confirm adequate overlap and seam bonding and that there is no damage or defects in the deployed GCL.

GCL placement shall not take place during periods of excessive winds and during dry periods only. Sandbags or other suitable means to prevent wind disturbance shall weigh down the GCL to prevent wind disturbances prior to placement of the subsequent layers.

All overlying layers should be placed in a way that prevents damage to underlying geosynthetic layers and does not entrap soil, stones or moisture that could damage or impair the performance of adjacent layers. Soil material placed over geosynthetic layers should be free of sharp or angular objects that could penetrate the geosynthetic material. In the case of geosynthetic clay liners, adjacent soil should not have high concentrations of calcium and should otherwise be chemically compatible with the liner.

Care must be taken to ensure no damage occurs to the GCL during its deployment and jointing operations. No equipment or tools shall be used which could damage the GCL by handling, trafficking or by any other means. Vehicular traffic should be avoided over installed geosynthetic layers. Foot traffic only should be allowed, except over hydrated geosynthetic clay liners. Site personnel should ensure that footwear and equipment used are free of sharp particles. Personnel working on the GCL shall not smoke or otherwise engage in any activity that could damage the GCL.

Throughout deployment, the Contractor shall undertake a survey to pick up all panels, joints and repairs and provide an as-built Drawing to the CQA Engineer for inclusion in the CQA Validation Report which will be submitted to the NSW EPA. This shall be fully referenced and show panel and roll reference numbers and any repair and sampling locations.

4.7 Damage, Defects and Repairs

Installation of the GCL shall be supervised by the CQA Engineer at all times. Should there be any signs of any damage, including manufacturer of installation damage, defects or contamination, these shall be clearly marked by the CQA Engineer.

The CQA Engineer shall advise the Contractor of any panels, or portions of panels, which are to be replaced or repaired. Damaged panels or portions of damaged panels, which have been rejected, shall be removed from the works area and replaced with replacement undamaged material.

Any damage to the GCL shall be repaired by placing a suitably sized patch of the same material and by overlapping of at least 500mm in all directions over the defect. Placement of sodium bentonite will be used to keep the patch in place. Sodium bentonite powder shall be evenly placed, giving full coverage around the damaged area of the patch prior to the placement of the patch to provide a better bond between the existing GCL panel and GCL patch.

All repaired sections of the GCL shall be marked on the panel deployment drawings.

4.8 Installation Approval

The completion of the GCL deployment shall be on a rolling hold point and assessed by the CQA Engineer. The signing off of the GCL panel deployment hold point shall be done by the CQA Engineer prior to the placement of the overlying geomembrane. Approval shall be made on the basis of the following:

- GCL panel overlaps are at the required minimum measurement;
- That there are no visible surface defects; and that the appropriate overlap and seam bonding between adjacent panels has been achieved;
- No excessive wrinkles or folds exist on the deployed GCL panel;
- Visual inspection to confirm that all large stones, or any other potentially deleterious materials have been removed from the surface of the GCL;
- All necessary repairs have been made and their locations recorded.

Following inspection and agreement of the installed GCL, approved areas shall be covered with the geomembrane at the earliest possible opportunity.

4.9 Construction Details

Construction details for Cells 1 & 2 and for the leachate dam are detailed within the construction drawings. Geosynthetics are to be formed into the anchor trenches as detailed within the drawings.

5 HDPE GEOMEMBRANE LINER

5.1 Geomembrane Material

The geomembrane shall consist of 2.0mm thick, high density polyethylene (HDPE) unlaminated material, textured on both sides and **shall comply with GRI GM13**. The material should be produced from pure (non-recycled) resins and contain no fillers, plasticisers or additives of any kind with the exception of carbon black. It is proposed that the Double Rough Sheet (DRS) geomembrane should be used on the base, side slopes and inter-cell bund, as identified within the Drawings.

In accordance with the NSW EPA Guidelines 2016, geomembrane liners should:

- consist of a thin plastic film, minimum 2 millimetres thick, manufactured from high density polyethylene or other material demonstrated to offer equivalent performance, strength and durability
- be strong enough to ensure adequate tear resistance, puncture resistance, and resistance to installation damage
- be able to resist degradation caused by factors such as chemical attack, temperature, oxidation and stress cracking over the entire life of the landfill (including the operating and post-closure periods)
- meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications; see GRI Test Method GM 13 and GRI Test Method GM 17 for, respectively, high density polyethylene geomembranes and linear low density geomembranes (Geosynthetic Research Institute, 2014a and 2014b).

5.2 Geomembrane Standards

The following standards are applicable at the time of drafting of this Specification and should be used for reference. The standards are the Geosynthetic Research Institute (GRI) standards and the American Society for Testing and Materials (ASTM) standards, as follows

5.2.1 GRI Standards

- GRI GM9 Standard Practice for Cold Weather Seaming of Geomembranes
- GRI GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet
- GRI GM13 Standard Specification for Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
- GRI GM14 Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
- GRI GM19 Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes
- GRI GM20 Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts
- GRI GM29 Standard Practice for Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and/or Non-destructive Testing

5.2.2 ASTM Standards

- ASTM D792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- ASTM D1004 Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting
- ASTM D1204 Standard Test Method for Linear Dimensional Changes of Non-rigid Thermoplastic Sheeting or Film at Elevated Temperature

- ASTM D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
- ASTM D1505 Standard Test Method for Density of Plastics by the Density Gradient Technique
- ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics
- ASTM D3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Colorimetry
- ASTM D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- ASTM D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
- ASTM D4437 Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes
- ASTM D4439 Standard Terminology for Geosynthetics
- ASTM D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
- ASTM D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- ASTM D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
- ASTM D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
- ASTM D5596 Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- ASTM D5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber
- ASTM D5721 Standard Practice for Air-Oven Aging of Polyolefin Geomembranes
- ASTM D5820 Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
- ASTM D5885 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Colorimetry
- ASTM D5994 Standard Test Method for Measuring the Core Thickness of Textured Geomembranes
- ASTM D6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
- ASTM D6392 Standard Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
- ASTM D6395 Standard Practice for Non-destructive testing of Geomembrane Seams using Spark Test
- ASTM D6693 Standard Test Method for Determining Tensile Properties of Non-Reinforced Polyethylene and Non-Reinforced Flexible Polypropylene Geomembranes
- ASTM D7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
- ASTM D7466 Standard Test Method for Measuring Asperity Height of Textured Geomembranes

5.3 Manufacturer's Quality Control

The manufacturer shall be certified AS/NZS ISO 9001:2000 which is audited by a third party accredited by the Joint Accreditation System of Australia and New Zealand (JAS-ANZ).

The manufacturer shall follow a quality control program, approved by the Superintendent, throughout the manufacturing of all HDPE geomembrane for the Works. The Contractor shall supply a quality control certificate for each batch of material delivered to site. The certificate shall contain as a minimum the parameters, test specifications and test values detailed in Table 4.

The Contractor shall provide the Superintendent with the following information:

- date of manufacture
- origin of the resin (resin supplier's name, resin production plant)
- identification of the resin (brand name, batch number)
- manufacturer quality control documentation for the particular lot of resin used in the production of the rolls delivered to the Works
- manufacturer's certificates, descriptive data, test results for geomembrane composition and properties and specification sheets
- a copy of the quality control certificates issued by the resin supplier noting results of density, melt index and carbon back tests
- Quality control program laboratory-certified reports with the manufacturer's approved quality assurance stamp and the laboratory technician's signature.
- reports on the tests conducted by the supplier to verify the quality of the sheet produced in the same batch or batches as the material supplied.

5.4 Manufacturers Quality Assurance

The manufacturer shall follow a quality assurance program, approved by the Superintendent, throughout the manufacturing of all HDPE geomembrane for the Works.

The frequency of sampling and testing shall be in accordance with ASTM D4354.

The Superintendent or CQA Engineer may reject any HDPE geomembrane rolls that have not been sampled and/or tested in accordance with this Specification. All HDPE geomembrane rolls rejected by the Superintendent or CQA Engineer shall be removed from the Works and replaced at the expense of the Contractor.

5.4.1 Contractor Requirements

The Contractor shall submit the following to the Superintendent and CQA Engineer for review and approval prior to delivery of HDPE geomembrane to site:

- Manufacturer's quality control and assurance test results;
- Statement on the origin of the resin, its identification (type and lot number), resin supplier's name and production plant, resin brand name and type, and the maximum amount of recycling polymer material added to the raw resin;
- Copies of quality control certificates issued by the resin supplier which shall include testing conducted to verify conformance with Table 4;
- Manufacturer's certificate of compliance outlining conformance with the requirements of this Specification;
- Certification that the HDPE geomembrane supplied for this work was manufactured as consecutive rolls from a single lot or from consecutive lots. If the HDPE geomembrane is not manufactured from consecutive lots, the resin manufacturer shall provide certification of quality and consistency of the resin characteristics;
- Certifications that the HDPE geomembrane and extrudate produced for the Works have the same properties and are of the same resin;
- Complete description of the manufacturer's shipping, handling and storage procedures;
- Manufacturer's installation procedures and requirements;

- Work method statement for HDPE geomembrane delivery, storage, handling and installation. This shall include seaming and jointing, welding, procedures for testing and repairing, proposed handling equipment and restraining methods, and other information that shall promote proper use

5.5 Geomembrane Material Requirements

The geomembrane materials shall meet the minimum requirements set out in Table 4.

The Contractor shall supply manufacturer's quality control and assurance testing results in accordance with the testing frequencies identified in Table 4 showing that the proposed material meets the requirements of Table 4. Samples taken shall be representative of the whole material source and shall be evenly distributed across the roll lots.

Table 4 2.0mm HDPE Geomembrane Requirements

Property	Standard	Units	Requirement	Minimum Test Frequency
Resin (base resin density without carbon black or additives)				
Density (min.)	ASTM D1505 or D792 (Method B)	g/cm³	0.932	Per resin lot
Melt index (max.)[1]	ASTM D1238	g/10min	1.0	Per resin lot
Sheet				
Thickness (min. average)	ASTM D5994	mm	1.9	Every roll
Lowest Individual roll thickness (of 8 of 10 readings)	ASTM D 5994	mm	1.8	Every roll
Lowest individual of 10 readings		mm	1.7	Every roll
Asperity Height (min. average)[2]	ASTM D7466	mm	0.4	Every other roll
Density (max)	ASTM D1505	g/cm³	<0.94	90,000 kg
Carbon Black Content (range)	ASTM D4218[3]	%	2 – 3	9,000 kg
Carbon Black Dispersion[4]	ASTM D5596	rating	Cat 1 or 2 only	20,000 kg
Tensile Properties (min. average)[5]	ASTM D6693	-	-	9,000 kg
1. Strength at break		N/mm	21	
2. Elongation at break		%	100	
3. Strength at yield		N/mm	29	
4. Elongation at yield		%	12	
Tear Resistance (min. average)	ASTM D1004	N	249	20,000 kg
Puncture Resistance (min. average)	ASTM D4833	N	534	20,000 kg
Stress crack resistance[6]	ASTM D5397	hr	600	Per each formulation
Dimensional stability	ASTM D1204	%	±2	90,000 kg

Oxidative Induction Time (OIT) (min. average)[7] - Standard OIT **and** - High Pressure OIT	 ASTM D3895 ASTM D5885	 min min	 100 400	90,000 kg
Oven Aging at 85ºC (min. average) - Standard OIT **and** - High Pressure OIT	ASTM D5721 ASTM D3895 ASTM D5885	% retained after 90 days	 55 80	Per each formulation
UV Resistance (min. average)[8] - High Pressure OIT[9]	ASTM D7238 ASTM D5885	% retained after 1600 hours	50	Per each formulation

1 Conducted at 190°C with 2.16 kg mass applied

2 Alternate the measurement side for double sided textured sheet

3 Other methods such as ASTM D1603 (tube furnace) or ASTM D6370 (TGA) are acceptable if an appropriate correlation to ASTM D4218 (muffle furnace) can be established

4 Carbon black dispersion (only near spherical agglomerates) for 10 different views: - 10 in categories 1 or 2 only, none in category 3

5. Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction:
   - HDPE yield elongation is calculated using a gage length of 33 mm
   - HDPE break elongation is calculated using a gage length of 50 mm

6 The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing

7 Samples to be evaluated at 30 and 60 days to compare with the 90 day response

8 The condition of the test should be 20 hour UV cycle at 75oC followed by 4 hour condensation at 60oC

9 UV resistance is based on percent retained value regardless of the original high pressure OIT value

5.6 HDPE Roll Identification

The Contractor shall provide the Superintendent or CQA Engineer with a quality control certificate for each roll. HDPE geomembrane rolls shall be identified in accordance with ASTM D4873. Each roll shall have affixed a label which identifies, as a minimum showing:

- Roll number
- Batch number
- Product and manufacturer name
- Date of manufacture
- Material thickness
- Roll length
- Roll width
- Roll weight
- The manufacturer's approved quality assurance stamp and the technician's signature

The Contractor shall record the Roll Number of every roll of liner used together with its destination(s) within the finished works.

5.7 Delivery, Handling and Storage

Delivery, storage and handling of all HDPE geomembrane rolls and samples shall be undertaken in accordance with the manufacturer's instructions and ASTM D4873.

Rolls shall be delivered to site, handled and stored in such a manner that no damage occurs to the rolls. The geomembrane liner shall be stored at a location to be agreed on site and shall not be stacked more than three rolls high.

Rolls shall be stored in a location away from haul routes, construction traffic etc but sufficiently close to the Landfill area to minimise handling. The storage area shall be smooth, level, dry, well-drained and stable. The Contractor shall take measures to protect the HDPE geomembrane from rainfall, chemicals, excessive heat, spills of oils or other hydrocarbons, UV radiation, animals/birds and vandalism.

No materials shall be placed on top of the stacked geomembrane liner.

Rolls shall be handled using a spreader bar. The bar shall be capable of supporting the full weight of the rolls without significant bending. Under no circumstances shall the rolls be dragged, lifted from one end, lifted in the middle of the roll, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle. The Contractor may nominate alternate handling equipment and plant for approval by the Superintendent as part of their work method statement.

The Contractor shall inspect all HDPE geomembrane rolls for defects and damage upon delivery.

5.8 Conformance Testing

As soon as practicable after the delivery of geomembrane to site the Contractor shall label and cut a sample 1m wide across the entire width of selected rolls under the direction of the CQA Engineer for conformance testing. A total of three sub samples of equal size shall be obtained from each main sample for the following purpose:

- 1 No. to be retained by the Contractor
- 1 No. to be retained by the CQA Engineer
- 1 No. to be tested at an independent NATA accredited Laboratory.

The Contractor shall submit the specified samples to the proposed independent, NATA accredited laboratory for conformance testing. All of the parameters listed in Table 5 (taken from Table 8 of the NSW EPA Guidelines 2016) will be tested.

Table 5 Geomembrane Conformance Testing Requirements

Property	Standard	Frequency
Thickness	ASTM D5994 (textured)	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Asperity height (textured)	ASTM D7466	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Density	ASTM D1505 or ASTM D792	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Tensile Properties (yield and break stress, yield and break elongation)	ASTM D6693	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Puncture Resistance	ASTM D4833	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Tear Resistance	ASTM D1004	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Carbon Black Content	ASTM D1603 or ASTM D4218	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Carbon Black Dispersion	ASTM D5596	1 test per 5000 m_2, including the first and last rolls (based on production order): minimum of two tests
Stress Crack Resistance	ASTM D5397	1 test per 10,000 m_2, or resin type or manufacturing run (whichever results in the greatest number of

		tests), including the first and last rolls (based on production order): minimum of two tests
Standard oxidative induction time **and** High-pressure oxidative induction time	ASTM D3895 ASTM D5885	1 test per 10,000 m_2, or resin type or manufacturing run (whichever results in the greatest number of tests), including the first and last roll (based on production order): minimum of two tests

In accordance with the NSW EPA Guidelines 2016 general requirements apply, as detailed below:

- Test results must be passed by the Construction Quality Assurance engineer before deployment of the geosynthetic material.
- All testing must be performed on samples taken from the geosynthetic rolls to be used for the works, with all sampling overseen by the Construction Quality Assurance engineer.
- All laboratory tests should be performed in a third-party, independent, accredited geosynthetics laboratory.
- Delivery of samples to the laboratory should be organised by the Construction Quality Assurance engineer, not the contractor. A suitable chain of custody procedure should be implemented.
- Test results should be sent directly from the laboratory to the Construction Quality Assurance engineer.
- The specified frequencies assume that all rolls are from a single continuous manufacturing run. The frequencies should be applied to each continuous manufacturing run producing the rolls to be used in the project.
- In the tables, 'ASTM methods' refers to standard test methods published by ASTM International (West Conshohocken, Pennsylvania, USA).
- The Construction Quality Assurance engineer should use his or her judgment as to whether independent conformance testing additional to the testing stipulated by the designer is required in particular circumstances during construction.
- If a sample records a non-conforming test result, it may be retested. If it passes this retest, both results should be provided in the laboratory report. If the retest produces a non-conforming result, the contractor should remove and replace all rolls between the sampled roll and the nearest conforming rolls either side (on the basis of the production order of the rolls). The contractor may, by testing and verification of these intermediate rolls, reduce the range of rolls to be removed in this way. Such additional testing should be for the full range of specified tests, not just the test or property that yielded a non-conforming result. Any replacement material should undergo the specified independent conformance testing.

The Contractor shall furnish to the CQA Engineer a copy of the laboratory test results immediately on receipt.

If rolls on site from previous projects are being used in the Works at least 1 conformance sample must be taken from these rolls. Rolls on site from previous projects shall only be used if the roll number, batch number and manufacturers details are known.

Any repairs or other works occasioned by the failure of the geomembrane to meet the minimum requirements listed in Table 5 shall be carried out at the Contractor's expense.

If a conformance sample cut from a roll fails to meet the test values listed in Table 5, the CQA Engineer may accept material from elsewhere on that roll if the Contractor can demonstrate through further laboratory testing that this material does meet the acceptance criteria contained in Table 5. Any such further testing shall be undertaken at the Contractor's expense.

5.9 Weather Conditions

The Contractor and lining installation crew shall review weather conditions daily to assess the suitability of installation. Installation or welding operations shall not proceed in the following circumstances:

- During rain, hail or excessive winds (typically greater than 30km/hr)
- In the presence of standing water or excessively wet surfaces, and
- When HDPE panel temperatures are <0° or >65° when measured by a calibrated infrared thermometer, surface thermocouple or similar approved.

5.10 Geomembrane Installers Experience

The Contractor shall provide to the Superintendent or CQA Engineer the following documentation:

- Certification that the Geosynthetic Installer's lead technician has a minimum of two hundred hectares of actual geosynthetic installation experience and a minimum of one hundred hectares of supervisory experience for geosynthetic installation;
- Certification that the geosynthetic installer's Seaming Foreman/Lead Technician is an International Association of Geosynthetic Installer's Certified Welding Technician and has a minimum of one hundred hectares of actual geosynthetic seaming experience and a minimum of fifty hectares of supervisory experience during the seaming of geosynthetic materials
- Certification that each individual on the geosynthetic installer's seaming crew has a minimum of ten hectares of geosynthetic seaming experience and a minimum of five hectares of seaming experience with geosynthetics similar to this Specification. There may also be present on site, one crew member who shall be designated as a Trainee Technician. Trainee Technicians may be allowed to carry out welding activities provided they are at all times under the direct supervision of the Crew Foreman or Lead Technician
- Certification indicating an approval or licence from the proposed geosynthetic manufacturers for the Contractor to install the manufacturer's materials

Copies of the suitable welders certificates shall be made available to the Superintendent, copies of which will also be included as part of the final CQA validation report.

5.11 Geomembrane Installation

HDPE geomembrane shall be installed within Cells 1 & 2 as well as within the proposed leachate dam as detailed within the drawings.

The Contractor shall prepare a work method statement for the installation of HDPE geomembrane for submission to the Superintendent for review and comment prior to installation of the HDPE geomembrane. The work method statement shall be developed in accordance with this Specification and the NSW EPA Guidelines 2016. The Superintendent or CQA Engineer may reject any HDPE geomembrane rolls that have not been installed in accordance with this Specification.

The Contractor or their approved geomembrane installer shall submit a detailed Geomembrane Panel Layout Plan showing the proposed layout and sequence of geomembrane installation not less than one week prior to commencing installation. Geomembrane panels shall be installed in accordance with the submitted Layout Plan as approved by the Superintendent or CQA Engineer.

The HDPE geomembrane shall be placed and seamed in accordance with this Specification, the Drawings, the approved work method statement and the manufacturer's instructions.

The HDPE geomembrane shall be installed in accordance with the following;

- The geomembrane shall be placed on the side slopes, base and inter-cell bunds.
- The geomembrane shall be placed to the back edge of the anchor trench, be formed on the side slopes and base and shall be free from cuts, holes, blisters, abrasions or other surface blemishes or defects.

- The Contractor shall arrange the panels so that seams are aligned parallel to the line of maximum slope (i.e. normal to contours), whenever practicable in accordance with accepted good practice, preventing surface water from flowing below previously installed geomembrane.
- HDPE geomembrane shall be installed without excessive wrinkling or tensioning.
- The geomembrane shall not be allowed to 'bridge over' voids or recesses.
- The geomembrane shall be placed to allow intimate contact with the compacted clay liner (base and lower side slopes) or underlying GCL (upper side slopes).
- HDPE geomembrane shall be cut from each roll with an approved hook blade safety knife.
- The geomembrane shall be placed such that the panels are anchored at the crest of the slope and form a continuous layer down the side walls and slopes and across the base of Landfill.
- Installation shall progress from the highest elevations to the lowest.
- The geosynthetic installers method of unrolling of the geomembrane shall not cause bridging, excessive wrinkles, indentations, scratches etc.
- The Contractor shall deploy the geomembrane close to its final position as practically possible to minimise the need for pulling the panel over the underlying GCL liner.
- HDPE geomembrane shall not be dragged across the ground as this will likely result in defects and damage to the rolls.
- Only geomembrane rolls which can be seamed or permanently anchored on at least two sides on the same day shall be installed on a working shift. All other open unwelded or un-anchored sides shall be temporarily surcharged, see Section 5.12.
- HDPE geomembrane installed on slopes shall be fixed in anchor trenches as soon as possible after deployment as shown on the Drawings and within this Specification.
- Anchor trench backfilling shall be undertaken when the temperature is coolest to minimise effects of material wrinkling and expansion. Folds and wrinkles caused by geomembrane panel installation or thermal expansion shall be minimised wherever possible.
- After placement, the HDPE geomembrane shall be free of excessive folds, wrinkles, creases and irregular stressing before the overlying protection geotextile is placed.
- The geomembrane liner installation crew are required to wear suitable footwear such that damage to the geomembrane liner does not occur, not smoke at any time when handling or working with the geomembrane liner, ensure that no naked flames are used during the works and ensure that no hydrocarbon sources are permitted onto the exposed geomembrane liner.
- The geomembrane seam overlap shall not be less than 150mm for dual hot wedge fusion welding to allow sufficient overlap to allow peel tests to be performed on the completed seam.
- At the time of installation, the Contractor shall assign to each field panel an "identification code" consistent with the approved panel layout plan. The Contractor and CQA Engineer shall record the identification code, location, and date of installation of each panel.
- The Contractor shall inspect each panel after placement and prior to seaming for damage and shall advise the Superintendent which panels or portions of panels are offered for acceptance or are to be repaired. Damaged panels or portions of damaged panels, which have been rejected, shall be marked and their removal from the work area shall be recorded by the Contractor. Repairs shall be made according to relevant clauses of this Specification.

5.12 Temporary Surcharge

Sandbags or equivalent surcharge shall be used as necessary to temporarily hold down the HDPE geomembrane to prevent uplift by wind. In case of high winds, continuous loading shall be placed along panel edges to minimise wind flow and potential uplift under the panels. Sandbags themselves shall be manufactured from materials that will not allow soil fines to pass through the bags and deposit onto the geomembrane surface.

The Contractor shall be responsible for the geomembrane at all times during the Contract and shall adopt whatever measures are necessary to ensure its stability and protect it from damage.

Any problems arising from the Contractor's failure to secure the geomembrane adequately during the contract shall be remedied at the Contractor's expense.

5.13 Seaming

5.13.1 General

The Contractor shall submit to the Superintendent method statements detailing the following as a minimum, not less than one week prior to commencing geomembrane installation.

- proposed seam welding equipment;
- proposed seam welding technique or techniques and their proposed applications;
- overlap widths and overlap preparation prior to seaming;
- proposed acceptable temperature ranges for extrudate and/or hot wedge welding apparatus; and
- proposed acceptable maximum seaming speed if automated machinery to be used.

Geomembrane seaming/welding shall be undertaken whilst considering the following:

- Geomembrane placement shall be limited to that which can be positioned and seamed in one day;
- Geomembrane shall be seamed by using either dual hot wedge fusion welding or extrusion welding apparatus;
- Within anchor trenches, seaming shall extend up the panels a minimum of 500 mm past the crest of the anchor trench or to the full extent of the anchor;
- Trail seams shall be completed each day prior to welding of positioned panels;
- Adjacent seams shall be orientated in a roof tile manner down-slope to promote runoff;
- Prior to welding, the prepared panel surfaces shall be free of oil, dust, dirt, foreign debris, or any other potential contaminants that would be detrimental to welding. Where contamination does occur, the prepared surfaces shall be thoroughly cleaned prior to the weld being completed;
- If seam overlap grinding is required, that seaming is completed no later than one hour after grinding in order to mitigate oxidation of the sheet
- Grinding does not extend beyond the edges of the weld
- There shall be no visible moisture in the area to be welded. If moisture is noted in the weld area, mitigation measures during seaming shall be employed as approved by the Superintendent;
- The Geosynthetic Installer shall have an independently calibrated handheld temperature measuring device to confirm the temperatures of each and every welding machine prior to the commencement of any test or field welds. All information regarding the results gained from the temperature device shall be recorded for each welding machine
- All field seaming operations shall be supervised by the Lead Technician / Seaming Foreman with no field seams being made without the Lead Technician / Seaming Foreman present.

5.13.2 Seaming Equipment and Products

The approved processes for field seaming are dual hot wedge fusion welding and extrusion welding. The fusion welding apparatus must be an automated vehicle mounted device, which produces a double seam with an intervening enclosed space.

Dual hot wedge fusion welding shall be the preferred method of welding and shall be used for primary welds between adjacent geomembrane panels. Extrusion welding shall only be used for detailed work, repair work, or in areas inaccessible for dual hot wedge fusion welding (where approved by the Superintendent)

Any generator used for the works shall not be placed directly upon the liner but placed on a rigid separator. Furthermore, to prevent geomembrane damage during welding, a smooth insulating plate or suitable fabric shall be placed beneath the hot welding and extrusion welding apparatus after usage.

Dual hot wedge apparatus

Dual hot wedge fusion welding shall utilise a split head wedge fusion weld apparatus, fusing the upper and lower overlapped geomembrane panels. Further fusion welding details are as follows:

- The dual hot wedge fusion welding shall form two contact fusion areas of a minimum width of 15 mm and a 5 mm minimum wide void between each of the separate parallel weld zones;
- The welding equipment shall be capable of continuously monitoring and controlling the temperature contact zone where the machine is fusing the geomembrane so as to ensure that changes to environmental conditions, such as gusting winds or ambient temperature fluctuations shall not adversely affect the integrity of the weld;
- Welded seams shall have a finished overlap of >150mm for dual hot wedge fusion welding in order to leave sufficient overlap to allow peel tests to be performed on the welded seam;
- equipment used for seaming shall not damage the liner.

Extrusion welding

The extrudate shall be manufactured from the same resin type used in the manufacture of the geomembrane sheet being welded. The Geosynthetic Installer shall provide to the Superintendent, certification from the geomembrane manufacturer that the relevant geomembrane and extrudate supplied for the works have the same properties and are of the same resin or batch.

During welding, the Geosynthetic Installer shall be responsible for regularly checking, calibrating and recording of the preheat air flow and temperature at the nozzle and the extrudate flow and temperature at the barrel outlet.

Additional extrusion welding considerations are as follows:

- After positioning of panels, oxidation by-products on the surface of the sheet shall be removed from the weld area by grinding. Grind marks however shall not be deeper than 10% of the geomembrane thickness.
- Prior to welding, the extrusion welder is purged prior to beginning a seam until all the heat-degraded extrudate has been removed from the barrel
- Seams shall have a finished overlap >75mm for extrusion welding in order to leave sufficient overlap to allow peel tests to be performed on the welded seam;
- The minimum width of the surface extruded bead shall be 30mm
- Welding shall be undertaken in one direction only

5.13.3 Trial Seams

The Contractor shall perform trial seams with each seaming machine and operator at least at the start of each shift, after every four hours of operation, following any period of machine shutdown or change of operator, if any welding stoppage exceeds one hour or if weather conditions change.

Trial seams shall be made under the identical conditions as the actual seams. All trial seams shall be carried out in the presence of the CQA Engineer.

Each seaming apparatus shall be allowed to warm up a minimum of 5 minutes before performing trial welds.

The trial seams shall be at least 1.5m long in the case of extrusion seams and at least 2.5m long in the case of fusion seams. The trial seam shall be stored on site until completion of the works and marked with the following information:

- trial seam number;
- date and time
- geomembrane temperature welding machine type and number.
- ambient air temperature

On completion of the trial seam, the Contractor shall cut six 25mm wide and 105mm long field tabs along the seam length, once having been allowed to cool. The tabs shall be subjected to field qualitative destructive testing using a tensiometer or field testing methods. Three of the six tabs shall be tested in peel mode and three samples tested in shear mode. The subsamples from each end shall immediately be tested onsite for peel and shear strength in accordance with GM19.

If any subsample does not meet the acceptance criteria, the seamer and seaming apparatus and/or methods shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive trial seams are successful.

The trial seam will be deemed to have passed qualitative destructive testing if the failure occurs solely in the parent material and does not enter the seam and achieves the values stated in GM19. The seam will be deemed to have failed qualitative destructive testing if any of the failure enters the seam.

Trial seaming and destructive testing will be observed by the CQA Engineer.

5.14 Field Seam Sampling and Testing

5.14.1 Destructive Seam Testing

Destructive seam testing is required to check that welded panels are fully integrated with each other to evaluate seam strength. Seam strength testing shall be undertaken as the seaming work progresses, not at the completion of field seaming. Destructive seam tests shall be performed at preselected locations determined by the CQA Engineer in consultation with the Contractor.

Destructive testing involves two techniques: 1) shear testing, and 2) peel testing. Shear testing applies a tensile stress from the top sheet through the weld and into the bottom sheet. Peel testing, on the other hand, peels the top sheet back against the overlapped edge of the bottom sheet to observe how separation occurs. The peel test indicates whether or not the sheets are continuously and homogeneously connected through the seam.

Destructive test samples shall be a minimum of 1,500 mm by 300 mm with the seam centred in the middle of the sample. The location of each destructive seam sample shall be up to the discretion of the CQA Engineer. The position of the destructive sample shall be marked and annotated on the panel deployment drawing, along with the date and time of sampling and the destructive sample number.

The destructive seam sample shall be cut into three subsamples (500mm by 300mm with seam centred). The two subsamples from each end shall be tested on-site for peel and shear strength to meet the requirements set out in Table 6.

Table 6 Geomembrane Destructive Seam Testing Requirements

Test Description	Test Method	Min. Test Frequency[1]	Acceptance criteria[2]
Peel strength[3]	ASTM D6392	1 test per 150m [(4)] (or part thereof)	As per GM19
Shear strength	ASTM D6392	1 test per 150m [(4)] (or part thereof)	As per GM19

1 A minimum of one series of destructive tests shall be performed each day that seaming is performed

2 All destructive test results shall be based on Film-Tear Bond (FTB) criteria. All samples which produce seam failures shall be considered unacceptable

3 Peel strength testing shall be performed on both Weld A and Weld B

4 When ambient air temperatures during seaming operations are less than 10oC, testing frequency shall be increased to one

test per 75 linear meters

Five 25mm wide tab specimens will be cut from each of the two sub-samples (10 in total). Alternate tabs will be tested for peel strength with the intervening tabs tested in shear using a tensiometer or field testing methods. If all on-site subsamples meet the acceptance criteria of Table 6, the central portion of the test sample shall be labelled and provided to the CQA Engineer for destructive testing at the Superintendent's independent NATA accredited testing laboratory.

If a field tab fails qualitative destructive testing, the Contractor shall either:

- reconstruct the seam between two tabs shown to have passed qualitative destructive testing
- cut further tabs from 3m to each side of the failed tab and subject these to qualitative destructive testing. If these tabs pass qualitative destructive testing the Contractor shall reconstruct the seam between the passed locations. If either sample fails, the Contractor shall cut and test further field tabs until he can identify an area bounded by two passed locations. The Contractor shall then reconstruct the failed seam.

The CQA Engineer reserves the right to request the cutting and destructive testing of further field tabs at any locations along the length of a seam.

Repair patches shall be extrusion welded over the areas where destructive seam samples have been taken and shall be subjected to non-destructive testing.

The CQA Engineer shall provide a copy to the Contractor of the formal report from the independent testing laboratory detailing the procedures used for testing and including a summary of all results.

5.14.2 Non-Destructive Seam Testing

The Contractor shall non-destructively test all field seams over their full length using a vacuum test unit, air pressure testing, or other approved method. The purpose of non-destructive testing is to check the continuity of seams. It does not provide information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of field testing.

The Contractor shall perform non-destructive testing along the entire lengths of all field seams including patches and repairs. The tests shall be undertaken no earlier than one hour after welding. In addition to the above tests, the welds shall be visually inspected to assess the quality of the workmanship and the appearance of the welded seam.

The Contractor shall submit not less than one week prior to commencing installation a method statement detailing the proposed non-destructive test technique or techniques and their proposed applications.

All seams shall be non-destructively tested over the entire length of seam by at least one of the methods in Table 7 below.

Table 7 Geomembrane Non-Destructive Seam Testing Requirements

Test Description	Test Method	Min. Test Frequency	Acceptance criteria
Air Pressure[1]	ASTM D5820	All seams to be tested by at least one of the test methods, as appropriate	No defects
Spark Test	ASTM D6365		• Min. pressure 210 kPa • Max. pressure 250 kPa • Max. pressure differential[2] 10 kPa
Vacuum Box	ASTM D5641		No spark

1 All needle punctures shall be repaired as per the requirements of this Specification

2 Observe and record the pressure 5 min after the initial reading. If the loss of pressure exceeds that shown, or if the pressure does not stabilize, the faulty area should be located and repaired

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. The Contractor shall then subject the repair to further non-destructive testing until the repair shall pass the test.

The Contractor shall advise the CQA Engineer when testing ready to commence, non-destructive testing shall not be performed unless the CQA Engineer is in attendance. The CQA Engineer will record the results of all non-destructive testing on the seam once testing has been carried out.

5.15 Geomembrane Defects and Repairs

The Contractor and shall be responsible for inspecting the placed geomembrane to identify and highlight any damage in the material. The CQA Engineer will also undertake ongoing quality assurance inspections of the deployed geomembrane and seaming.

All patches shall be of the same compound and thickness as the geomembrane being patched over.

Any area of the geomembrane that has been damaged during deployment, installation or seaming shall be repaired by the Contractor under the supervision of the CQA Engineer. All repairs shall be verified, photographed and recorded by the CQA Engineer.

Every repair requiring a patch or cap strip shall be non-destructively tested using the methods described in the relevant clauses of this Specification as appropriate and recorded by the CQA Engineer. Passing of the non-destructive test shall be taken as an indication of an adequate repair.

Failed tests indicate that the repair shall be re-done and re-tested until a passing test result is achieved. Work shall not proceed with any materials which will cover locations which have been repaired, until field and/or laboratory test results with passing values are available. Large cap strips may require destructive testing as directed by the CQA Engineer.

The Contractor shall submit to the CQA Engineer a log containing details, including dates, locations and types of repairs undertaken of all defects identified.

All defects in the geomembrane (whether caused by installation damage, manufacturing defect or by seaming) shall be repaired by the Contractor in the following manner:

5.15.1 Smaller Defects:

Smaller punctures, pin holes, blemishes, blisters, small tears and localised imperfections shall be repaired using a patch with the patch extending a minimum of 150mm beyond the edge of the defect.

5.15.2 Larger Defects

The faulted area shall be cut back to remove all imperfections and shall be overlain with a single piece of compatible geomembrane to give a minimum overlap of 150mm in all directions. Patches shall have rounded edges (minimum radius of 75 mm). The area shall then be prepared and seamed in accordance this Specification. Patches shall be seamed using extrusion welding.

5.15.3 Seam and Large Tear Defects

Defective seams and large tears shall be overlain with a single piece of compatible geomembrane with a minimum overlap of 150mm in all directions to form a cap strip. The repair may then be completed as for large faults. No re-seaming over existing seams shall be permitted.

Faulted fusion seams shall be cut back to remove the upper flap, prepared and extrusion welded in accordance with this Specification.

5.15.4 Excessive Wrinkles

Excessive wrinkles which may become creased or overfolded during backfilling shall be cut and subsequently repaired. Excessive wrinkles may be defined as a wrinkle which at the time of covering, and in the opinion of the CQA Engineer, meets any of the following criteria:

- Is nominally >200mm in height
- May have the ability to overfold during loading

5.15.5 T-Joins

T-joins in fusion welds shall be extrusion welded and air channels sealed.

All repair seams shall be made in accordance with the requirements of Seaming Section 5.13.

5.16 Geomembrane Installation Records

The Contractor and CQA Engineer shall keep and compile quality assurance forms, test results, data sheets etc in accordance with the approved CQA Plan and Specification, including the following;

- Reports on all QA testing carried out on the HDPE geomembrane
- As built panel layout drawings, showing panel numbers, seam numbers, defect/repair locations, and destructive sample locations
- Welding records
- QA documentation including panel deployment log, trial seam log, seaming logs, destructive sample log, non-destructive seam log.

5.17 Construction Details

Site specific construction requirements are outlined as follows;

- The geomembrane shall be installed to the grades shown on Figure No. 6, 7and 12.
- Shoulders of the anchor trench shall be slightly rounded when a geomembrane adjoins the trench to minimise sharp bends in the key in trench.
- The geomembrane shall be installed and welded to the back of the anchor trench as shown within the Drawings.
- Anchor trench backfill shall be selected compacted clay liner material and installed in lifts not exceeding 150mm and compacted with a wacker plate or other means approved by the CQA Engineer.
- Clay fill used to recompact the anchor trenches shall be placed to the same moisture content and compaction requirements as the sub-base fill and bunds.

6 GEOTEXTILES

6.1 General

Two geotextiles are required for the construction of the proposed Landfill, namely the protection (or cushion) geotextile and the separation (filter) geotextile. The protection geotextile is designed to increase the resistance of the HDPE geomembrane from puncture or abrasion from the point loadings and skewing imposed during the placement of the aggregate drainage blanket. Furthermore, the protection geotextile assists in long term longevity of the geomembrane from the waste loading and settlement stresses implied. The separation geotextile is designed to have appropriate filtration characteristics to limit the effects of clogging of the underlying leachate collection aggregate from migration of soil fines.

The protection geotextile shall be deployed within Cells 1 & 2 only, it is not required for the leachate dam.

6.2 Protection Geotextile Material

In accordance with the NSW EPA Guidelines 2016, the protection or cushion geotextile should:

- be a non-woven, needle-punched geotextile, typically made of polyester or polypropylene (with the exception of inhibitors and/or carbon black added for UV resistance), formulated to meet landfill conditions and not containing recycled materials.
- be of sufficient mass, strength and thickness to protect the underlying geomembrane from puncture and from excess stresses and strains due to indentations from overlying gravel particles or from the ribbing, edges and joints of drainage geocomposites.
- meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications. See GRI Test Method GT12(a) and GRI Test Method GT12(b) (Geosynthetic Research Institute, 2012a and 2012b).

The grade (mass, strength, thickness) of the protection geotextile should be justified by the results of site-specific liner testing. This testing should incorporate the proposed liner and adjacent layers and apply the estimated confining pressures that will be experienced in service as a result of the overlying waste and equipment loadings.

Two published methods for examining the expected field performance of a geomembrane liner under gravel aggregate are: (1) LFE 2 – Cylinder Testing Geomembranes and their Protective Materials: A methodology for testing protector geotextiles for their performance in specific site conditions (UK Environment Agency, 2014); and (2) ASTM D5514 / D5514M-14, Standard Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics (ASTM International, 2014). In these tests, a representative load is applied under standard conditions to a sample comprising the proposed drainage material, protection geotextile and geomembrane liner. Measurements are taken of the deformations in the liner. Strains in the material are estimated from the deformation data and should be compared with the acceptable values for geomembrane strain listed in NSW EPA Guidelines 2016 Table 2. Excessive strain can lead to environmental stress cracking in the liner over time. The testing should ensure that both short-term and long-term effects are taken into account. The maximum allowable strain for a textured HDPE geomembrane is 4%.

The geotextile shall be non-woven, needle punched, needle free resin or heat bonded manufactured from polyester, polyethylene or polypropylene. The geotextile shall comprise polymeric yarns or fibres, seamed or drawn strands orientated into a stable network which retains its structure during handling, placement and long term service. The geotextile filaments shall be rot-proof, chemically stable, with no water absorbency and the filaments being able to resist delamination.

The protection geotextile (cushion geotextile) shall be installed directly above the geomembrane and anchored as shown within the Drawings.

6.3 Relevant Standards

The following standards are applicable at the time of drafting of this Specification and should be used for reference. The standards are the American Society for Testing and Materials (ASTM) standards, Geosynthetic Research Institute (GRI) standards and Australian Standards (AS), as follows

6.3.1 ASTM Standards

- ASTM D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
- ASTM D4355 Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water
- ASTM D4439 Standard Terminology for GeosyntheticsD4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity
- ASTM D4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles
- ASTM D4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
- ASTM D4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile
- ASTM D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
- ASTM D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- ASTM D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
- ASTM D5514 Standard Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics
- ASTM D6767 Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test

6.3.2 GRI Standards

- GRI GT12(a) Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials
- GRI GT13(a) Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate

6.3.3 Australian Standards

- AS 2001.2.3 Methods of test for textiles - Physical tests - Determination of breaking force and extension of textile fabrics
- AS 3704 Geosynthetics-Glossary of Terms
- AS 3705 Geotextiles-Identification, marking and general data
- AS 3706.3 Determination of tearing strength - Trapezoidal method
- AS 3706.4 Determination of burst strength - California bearing ratio (CBR) - Plunger method
- AS 3706.7 Determination of pore-size distribution - Dry-sieving method
- AS 3706.9 Determination of permittivity, permeability and flow rate

6.4 Manufacturer's Quality Control

The manufacturer shall follow a quality control program, approved by the Superintendent, throughout the manufacturing of all geotextiles for the Works. The Contractor shall supply a quality control certificate for each batch of material delivered to site. The certificate shall contain as a minimum the parameters, test specifications and test values detailed in Table 8.

The Contractor shall provide the Superintendent with the following information:

- date of manufacture
- Lot number and roll number,
- roll dimensions including length and width
- geotextile manufacturer quality control documentation for the particular lots/rolls for geotextiles delivered
- accredited laboratory quality control certificates
- manufacturer's Quality Assurance

The Contractor or nominated installer shall be responsible for quality assurance and quality control of the manufacture, transport and installation of the geotextiles. The CQA Engineer shall undertake quality assurance alongside the Contractor. The Contractor shall provide the CQA Engineer with all necessary documentation required to complete the Validation Report at completion of the works.

The Contractor shall provide the CQA Engineer with necessary literature to fully demonstrate that the materials proposed fully comply with the requirements of the Specification. Such information shall include the manufacturer's test results for the product, including composition, mechanical and physical properties, and shall be provide at least seven days prior to delivery.

6.5 Manufacturer's Quality Assurance

The manufacturer shall follow a quality assurance program, approved by the Superintendent, throughout the manufacturing of all geotextiles for the proposed Landfill works.

The frequency of sampling and testing shall be in accordance with ASTM D4354.

The Superintendent or CQA Engineer may reject any geotextile rolls that have not been sampled and/or tested in accordance with this Specification. All geotextile rolls rejected by the Superintendent or CQA Engineer shall be removed from the Works and replaced by the Contractor at their own expense.

6.6 Geotextile Material Requirements

6.6.1 Protection Geotextile

The protection geotextile materials shall meet the minimum requirements set out in Table 8, and be needle free.

The Contractor shall supply manufacturer's quality control and assurance testing results in accordance with the testing frequencies identified in Table 8 showing that the proposed material meets the requirements of Table 8. Samples taken shall be representative of the whole material source and shall be evenly distributed across the roll lots.

Table 8 Protection Geotextile Requirements

Property	Standard	Units	Requirement[1]	Minimum Test Frequency
Mass per Unit Area (MARV)[2]	AS 3706.1	g/m^2	≥ 500	Every 2,500m^2
Grab Tensile Strength	AS 3706.2b	N	≥ 800	Every 5,000m^2
Trapezoidal Tear Strength (MARV)	AS 3706.3	N	≥ 700	Every 5,000m^2
CBR Burst Strength (MARV)	AS 3706.4	N	≥ 5000	Every 5,000m^2
UV Stability[3]	ASTM D4355	%	70	Each Lot

1 Indicative specification, as protection geotextile must be able to limit strain within the underlying HDPE geomembrane to less than 4%.

2 MARV = Mean Average Roll Value representing a confidence level of 97.5% of test results meet the required value.

3 Strength retained after 500 hours
Protection geotextile shall be **NEEDLE FREE**

As stated in Section 6, the grade (mass, strength, thickness) of the protection geotextile should be justified by the results of site-specific liner testing. This testing should incorporate the proposed liner and adjacent layers and apply the estimated confining pressures that will be experienced in service as a result of the overlying waste and equipment loadings. The Contractor shall undertake compression testing in accordance ASTM D5514 at a given kPa (to be provided), with the proposed underlying HDPE geomembrane and overlying leachate drainage aggregate.

The results of the compression testing shall be provided by the Contractor to the Superintendent to verify the proposed protection geotextile can meet the HDPE geomembrane strain acceptance criteria. The Contractor shall allow for all necessary compression testing in their rates.

Table 8 provides a preliminary specification only for the protection geotextile until strain testing has been undertaken, Table 8 can be used for preparation of tender price submissions.

Geotextiles shall be UV stabilised by incorporating a minimum 1% by weight active carbon black or an approved chemical UV stabiliser, to retain at least 70% of the initial grab tensile strength when tested for 500 hours in accordance with AS 3706 *Geotextiles – Methods of Test*.

The geotextile manufacturer shall provide production test certificates for rolls delivered to site demonstrating that the test values specified for the proposed product have been attained.

6.6.2 Separation Geotextile

In accordance with the NSW EPA Guidelines 2016, the separation geotextile should:

- be a non-woven, needle-punched geotextile, typically made of polyester or polypropylene (with the exception of inhibitors and/or carbon black added for UV resistance), formulated to meet landfill conditions and not containing recycled materials
- have appropriate filtration characteristics to limit the effects of clogging, while at the same time limiting excessive migration of soil fines into the underlying drainage layer
- allow flow of leachate into the underlying drainage layer without significant flow impedance
- have sufficient strength to resist installation damage
- have appropriate UV resistance properties based on the estimated exposure of the material before covering
- have appropriate chemical resistance to the site's leachate
- meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognised industry standard specifications. See GRI Test Method GT13(a) and GRI Test Method GT13(b) (Geosynthetic Research Institute, 2012c and 2012d).

The separator geotextile shall meet the minimum requirements detailed within Table 9.

The Contractor shall supply manufacturer's quality control and assurance testing results in accordance with the testing frequencies identified in Table 9 showing that the proposed material meets the requirements of Table 9. Samples taken shall be representative of the whole material source and shall be evenly distributed across the roll lots.

Table 9 Separation Geotextile Requirements

Property	Standard	Units	Requirement[1]	Minimum Test Frequency
Grab Tensile Strength	AS 3706.2b	N	≥800	Every 5,000m^2
Grab Elongation	AS 3706.2b	%	50	Every 5,000m^2
Trapezoidal Tear Strength (MARV)	AS 3706.3	N	≥310	Every 5,000m^2

CBR Burst Strength (MARV)	AS 3706.4	N	≥2400	Every 5,000m2
Permittivity (MARV)	AS 3706.9	s-1	0.5	Every 5,000m2
Pore size (MaxARV)	ASTM D6767	μm	120	Every 5,000m2
UV Stability3	ASTM D4355	%	70	Each Lot

1 Indicative specification, as protection geotextile must be able to limit strain within the underlying HDPE geomembrane to less than 4%.

2 MARV = Mean Average Roll Value representing a confidence level of 97.5% of test results meet the required value.

3 Strength retained after 500 hours

Separation geotextile shall be NEEDLE FREE

6.7 Geotextile Roll Identification

The Contractor shall provide the Superintendent or CQA Engineer with a quality control certificate for each geotextile roll. Geotextile rolls shall be identified in accordance with AS 3705. Each roll shall have affixed a label which identifies, as a minimum showing:

- Roll number
- Lot/Bale or Batch number
- Product and manufacturer name
- Date of manufacture
- Material thickness
- Roll length
- Roll width
- Roll weight
- The manufacturer's approved quality assurance stamp

The Contractor shall record the Roll Number of every roll of geotextile used together with its destination(s) within the finished works.

6.8 Delivery, Handling and Storage

Delivery, storage and handling of all HDPE geomembrane rolls and samples shall be undertaken in accordance with the manufacturer's instructions and ASTM D4873.

Rolls shall be delivered to site, handled and stored in such a manner that no damage occurs to the rolls. The geotextile shall be delivered to site in intact protective wrappings to protect rolls from degradation due to ultra violet light. The geotextiles shall be stored at a location to be agreed on site and shall not be stacked more than three rolls high.

Rolls shall be stored in a location away from haul routes, construction traffic etc but sufficiently close to the Landfill area to minimise handling. The storage area shall be smooth, level, dry, well-drained and stable. The Contractor shall take measures to protect the HDPE geomembrane from rainfall, chemicals, excessive heat, spills of oils or other hydrocarbons, UV radiation, animals/birds and vandalism.

No materials shall be placed on top of the stacked geotextiles.

Rolls shall be handled using a spreader bar. The bar shall be capable of supporting the full weight of the rolls without significant bending. Under no circumstances shall the rolls be dragged, lifted from one end, lifted in the middle of the roll, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle. The Contractor may nominate alternate handling equipment and plant for approval by the Superintendent as part of their work method statement.

The Contractor shall inspect all geotextile rolls for defects and damage upon delivery.

The Superintendent or CQA Engineer may reject any geotextile rolls that have not been delivered, stored or handled in accordance with manufacturers recommendations or in accordance with this Specification. Any rejected rolls shall be removed from the site and replaced at the expense of the Contractor.

Geotextiles shall be protected at all times against physical or chemical damage. Geotextiles shall be kept in the wrappings provided by the manufacturer until required for use in the works.

6.9 Conformance Testing

As soon as practicable after the delivery of geotextile to site the Contractor shall label and cut a sample 1m wide across the entire width of selected rolls under the direction of the CQA Engineer for conformance testing. A total of three sub samples of equal size shall be obtained from each main sample for the following purpose:

- 1 No. to be retained by the Contractor
- 1 No. to be retained by the CQA Engineer
- 1 No. to be tested at an independent NATA accredited Laboratory.

The Contractor shall submit the specified samples to the proposed independent, NATA accredited laboratory for conformance testing.

For protection geotextiles, all of the parameters listed in Table 10 (taken from Table 11 of the NSW EPA Guidelines 2016) will be tested.

For separation geotextiles, all of the parameters listed in Table 11 (taken from Table 12 of the NSW EPA Guidelines 2016) will be tested.

Table 10 CQA Testing Requirements for Protection Geotextiles

Property	Standard	Minimum Test Frequency
Mass per Unit Area	AS 3706.1	1 test per 2,500m$_2$, including the first and last rolls (based on production order): minimum of two tests
Grab Tensile Strength	AS 3706.2b	1 test per 5,000m$_2$, including the first and last rolls (based on production order): minimum of two tests
Trapezoidal Tear Strength	AS 3706.3	1 test per 5,000m$_2$, including the first and last rolls (based on production order): minimum of two tests
CBR Burst Strength (MARV)	AS 3706.4	1 test per 5,000m$_2$, including the first and last rolls (based on production order): minimum of two tests

Table 11 CQA Testing Requirements for Separation Geotextiles

Property	Standard	Minimum Test Frequency
Grab Tensile Strength	AS 3706.2b	1 test per 5,000m$_2$, including the first and last rolls (based on production order): minimum of two tests
Trapezoidal Tear Strength	AS 3706.3	1 test per 5,000m$_2$, including the first and last rolls (based on production order): minimum of two tests
CBR Burst Strength (MARV)	AS 3706.4	1 test per 5,000m$_2$, including the first and last rolls (based on production order): minimum of two tests
Pore size	ASTM D6767	1 test per 5,000 m$_2$, including the first and last rolls (based on production order): minimum of two tests

Permittivity	AS 3706.9	1 test per 5,000 m_2, including the first and last rolls (based on production order): minimum of two tests

The following requirements apply, as detailed below:

- Geotextile conformance test results must be passed by the Construction Quality Assurance engineer before deployment of the geosynthetic material.
- All testing must be performed on samples taken from the geosynthetic rolls to be used for the works, with all sampling overseen by the Construction Quality Assurance Engineer.
- All laboratory tests should be performed in a third-party, independent, NATA accredited geosynthetics laboratory.
- The specified frequencies assume that all rolls are from a single continuous manufacturing run. The frequencies should be applied to each continuous manufacturing run producing the rolls to be used in the project.
- The Construction Quality Assurance Engineer should use their judgment as to whether independent conformance testing additional to the testing stipulated by the designer is required in particular circumstances during construction.
- If a sample records a non-conforming test result, it may be retested. If it passes this retest, both results should be provided in the laboratory report. If the retest produces a non-conforming result, the contractor should remove and replace all rolls between the sampled roll and the nearest conforming rolls either side (on the basis of the production order of the rolls). The contractor may, by testing and verification of these intermediate rolls, reduce the range of rolls to be removed in this way. Such additional testing should be for the full range of specified tests, not just the test or property that yielded a non-conforming result. Any replacement material should undergo the specified independent conformance testing.

The Contractor shall furnish to the CQA Engineer a copy of the laboratory test results immediately on receipt.

If rolls on site from previous projects are being used in the Works at least 1 conformance sample must be taken from these rolls. Rolls on site from previous projects shall only be used if the roll number, batch number and manufacturers details are known.

Any repairs or other works occasioned by the failure of the geotextiles to meet the minimum requirements listed in Tables 10 and 11 shall be carried out at the Contractor's expense.

If a conformance sample cut from a roll fails to meet the test values listed in Table 10 or 11, the CQA Engineer may accept material from elsewhere on that roll if the Contractor can demonstrate through further laboratory testing that this material does meet the acceptance criteria. Any such further testing shall be undertaken at the Contractor's expense.

6.10 Weather Conditions

The Contractor and lining installation crew shall review weather conditions daily to assess the suitability of installation. Installation or welding operations shall not proceed in the following circumstances:

- During rain, hail or excessive winds (typically greater than 30km/hr)
- In the presence of standing water or excessively wet surfaces

6.11 Geotextile Installation

The method of installation shall not impose stresses or strains likely to cause damage to the geotextiles. Construction equipment must not operate directly on the geotextile.

The geotextiles shall be placed and seamed in accordance with manufacturer's instructions, this Specification and Drawings and in accordance with the Contractors approved method statement detailed below.

The Contractor shall prepare a work method statement for the installation of the geotextiles for submission to the Superintendent for review and comment prior to installation. The work method statement shall be developed in accordance with this Specification and the NSW EPA Guidelines 2016. The Superintendent or CQA Engineer may reject any geotextile rolls that have not been installed in accordance with this Specification.

The protection geotextile shall be deployed over the surface of the installed HDPE geomembrane on the floor, side walls and any intercell bund (see Figure No. 6 & 7). The separation geotextile shall be deployed over the surface of the emplaced drainage aggregate (see Figure No. 7 & 9). The separation geotextile shall be surcharged with aggregate filled sand bags to mitigate wind uplift, at maximum 2m centres. The Contractor must allow for the surcharging of the separation geotextile within the placement rate.

The geotextile shall be installed in accordance with the following;

- The protection geotextile shall be placed to the back edge of the anchor trench, be formed on the side slopes and base and shall be free from cuts, holes, tears, abrasions or other defects.
- The Contractor shall arrange the panels so that seams are aligned parallel to the line of maximum slope (i.e. normal to contours), whenever practicable in accordance with accepted good practice, preventing surface water from flowing below previously installed geotextile.
- Geotextiles shall be installed without excessive wrinkling or tensioning.
- The geotextile shall be placed to allow intimate contact with the underlying HDPE geomembrane.
- Geotextiles shall be cut from each roll with an approved hook blade safety knife.
- The protection geotextile shall be placed such that the panels are anchored at the crest of the slope and form a continuous layer down the side walls and slopes and across the base of Landfill.
- Installation shall progress from the highest elevations to the lowest.
- The geosynthetic installers method of unrolling of the geotextiles shall not cause bridging and excessive wrinkles etc.
- The Contractor shall deploy the geotextiles close to its final position as practically possible to minimise the need for pulling the panel over the underlying HDPE geomembrane liner.
- Geotextile shall not be dragged across the HDPE geomembrane (in the case of protection geotextile) or drainage aggregate (in the case of separation geotextile) as this will likely result in defects and damage to the rolls.
- Only geotextile rolls which can be seamed or permanently anchored on at least two sides on the same day shall be installed on a working shift. All other open unwedled or un-anchored sides shall be temporarily surcharged with sandbags or similar to prevent wind uplift and subsequent damage.
- Geotextile installed on slopes shall be fixed in anchor trenches as soon as possible after deployment as shown on the Drawings and within this Specification.
- The geotextile shall be free of excessive folds, wrinkles, creases and irregular stressing.
- The geotextile installation crew are required to wear suitable footwear such that damage to the geotextiles does not occur, not smoke at any time when handling or working with the geotextiles, ensure that no naked flames are used during the works and ensure that no hydrocarbon sources are permitted onto the exposed geotextiles.
- Joints shall be clean and free from excessive moisture or foreign matter. Joints shall be formed by hot air welding or stitching.
- The material at the joints will overlap by 200mm for hot air welding and by 150mm for stitching. A two-thread, double-locked stitch shall be used. The proposed seaming method shall be in accordance with the manufacturer’s instructions and recommendations.

- Stitching thread shall be a polymeric thread with physical and chemical-resistance properties that equal or exceed those of the host geotextile.
- Overlaps between panels of separator geotextile shall be minimum 500mm.
- The proposed method of jointing is to be submitted to the Superintendent and CQA Engineer seven days prior to commencement for consideration and approval.
- The geotextile panels shall be deployed by hand in either pre-cut lengths or pulled from a spreader bar attached to an excavator outside of the geomembrane lined area.
- Extreme care shall be afforded to the underling geomembrane when cutting any overlying geotextiles.
- The Contractor shall ensure that the seaming method does not result in damage to the underlying HDPE geomembrane.
- Seams shall provide seam strength which greater than or equal to 75% of the host geotextile material strength when tested in accordance with AS 3706.2 (host geotextile strength) and AS 3706.6 (seam strength).
- At the time of installation of the protection geotextile, the Contractor shall assign to each field panel an “identification code” consistent with the approved panel layout plan. The Contractor and CQA Engineer shall record the identification code, location, and date of installation of each panel.
- The Contractor shall inspect each panel after placement and prior to seaming for damage and shall advise the Superintendent which panels or portions of panels are offered for acceptance or are to be repaired. Damaged panels or portions of damaged panels, which have been rejected, shall be marked and their removal from the work area shall be recorded by the Contractor. Repairs shall be made according to relevant clauses of this Specification.
- The geotextile panels shall be temporarily surcharged by sandbags or suitable equivalent. The sandbags shall be installed at suitable spacing to mitigate wind uplift, and shall remain in place until covered with either leachate drainage aggregate in the case of the protection geotextile, or waste in the case of the separation textile.

6.12 Defects and Repairs

The CQA Engineer shall identify any area of defect and make an annotation on the geotextile surface by either spray paint or suitable marker.

The Contractor shall make good the area by removing any offending or deleterious matter and cutting a geotextile patch from the same material with a minimum 300mm overlap in all directions and securing by heat bonding.

The Contractor shall submit to the CQA Engineer or Superintendent for review a log containing details of any defects identified and repairs carried out.

6.13 Sign Off

The protection and separation geotextile shall be accepted by the Principal when the following conditions are met:

- The CQA Engineer is satisfied that all geotextile panels have been deployed and seamed in accordance with the Specification and manufacturers recommendations.
- All test results have been received by the CQA Engineer and verified as having met the requirements of the Specification
- Sufficient number and type of sandbags or similar approved have been placed across the surface of any protection and separation geotextile to prevent wind uplift to be left exposed at the completion of the Works.
- The Superintendent has inspected and approved the finished geotextile hold point.

6.14 Construction Details

The protection and separator geotextiles shall be installed as detailed within the Drawings.

The HDPE geomembrane shall be cleared of any offcuts, peel and shear testing tabs, inner rolls, lifting straps, construction and soil debris, wrappings etc prior to the deployment of the overlying protection geotextile

The geotextile protector shall be installed within a partially backfilled anchor trench to allow preferential pull out if the lining system comes into tension. Anchor trench backfill shall be installed in lifts not exceeding 150mm and compacted with a suitably sized wacker plate or other means approved by the CQA Engineer ensuring that no damage to the protection geotextile or underlying HDPE occurs as a result of backfilling.

A double layer of protection geotextile (heat bonded to the underlying primary protection geotextile) shall be placed beneath the leachate drainage aggregate in the vicinity of the leachate collection sump, as detailed within the Drawings.

The separation geotextile shall have an overlap with the protection geotextile on the side slopes and any intercell bund by a distance greater than 1,000mm. The separator geotextile may be deployed in phases in advance of waste placement to minimise wind uplift, UV exposure and general damage. The Contractor shall liaise with the Principal as to their requirements for full separator geotextile coverage.

7 LEACHATE COLLECTION AND EXTRACTION SYSTEM

7.1 General

The leachate collection and extraction system (LCES) shall incorporate a drainage aggregate layer utilising a 20-40mm aggregate of minimum 300mm thickness and slotted collection pipework in accordance with Drawing No. 7 and 8.

The Contractor shall inspect the surface of the geotextile protection layer for compliance with this document and seek approval from the Superintendent / CQA Engineer, prior to deployment of the drainage aggregate layer and collection/extraction pipework.

The Contractor shall submit a Method Statement to the CQA Engineer, as soon as practical, detailing how each element of the LCES will be handled, stored and installed within the works.

7.2 Relevant Aggregate Standards

The following aggregate standards are applicable at the time of drafting of this Specification and should be used for reference. The standards are Australian Standards (AS) and are as follows

- AS 1141.3.1 Methods for Sampling and Testing Aggregates – Sampling of aggregates and rock.
- AS 1141.11 Methods for Sampling and Testing Aggregates – Particle size distribution/dry sieve.
- AS1289.6.7.1 Methods for Testing Soils for Engineering Purposes – Determination of the permeability of a soil.

7.3 Leachate Drainage Aggregate

In accordance with Section 1.4 of the NSW EPA Guidelines 2016, the drainage material should:

- consist of hard, strong, durable and clean gravel that will maintain the required performance under the maximum loads likely to be imposed on it in service
- have a saturated hydraulic conductivity greater than 1 x 10_{-3} m/s when tested in accordance with Australian Standard AS 1289.6.7.1 Determination of the Permeability of a Soil (constant head method)
- be relatively uniform in particle size, with a nominal particle size greater than 20 millimetres and a maximum particle size of 40 millimetres, and with not more than 10% of particles smaller than 20 millimetres in diameter and not more than 3% smaller than 0.075 millimetres
- be non-reactive in mildly acidic conditions and chemically resistant to the leachate in the landfill, with a calcium carbonate content of less than 8.5% by mass
- not have a shape and angularity that will damage the underlying geomembrane liner (the best type of gravel is rounded and smooth-surfaced)

The following acceptance criteria and testing requirements apply.

Table 12 Drainage Aggregate Requirements and Testing

Property	Standard	Requirement	Min. Test Frequency
Particle Size Distribution -Passing 50mm -Passing 19mm -Passing 0.075mm	AS 1141.11,12,13 or AS 1289.3.6.1, 3.6.3	 100% ≤ 10% ≤ 3%	Greater of 1 test per 500m_3 of material or 2 per source
Constant Head Permeability	AS 1289.6.7.1	>1x10_{-3} m/s	Greater of 1 test per 500m_3 of material or 2 per source
Minimum Soaked 10% Fines Value	BS 812-111:1990 or AS 1289.6.7.1	100kN	Greater of 1 test per 500m_3 of material or 2 per source

Calcium Carbonate Content	Rapid Titration as per 'Soil and Plant Analysis' by C.S Piper		Greater of 1 test per 500m3 of material or 3 per source

Source material should be tested by the Contractor to show that the aggregate drainage material meets the Table 12 requirements.

The aggregate material shall not be subject to weathering, and shall be durable to the extent that minimal breakdown or degradation of the material occurs during placement and compaction

The particles shall meet or exceed the requirements for medium strength rock in accordance with AS 1726.

The blanket shall be installed to a minimum thickness of 300mm. All material shall be sampled from the quarry by the Contractor prior to the material being approved on site.

7.4 Installation

Prior to installation of the leachate drainage aggregate, the Contractor shall provide a survey of the completed protection geotextile as the basis for the commencement levels for aggregate drainage layer thickness.

The Contractor shall also provide a work method statement for placement and testing of the drainage aggregate, showing how the Contractor proposes to ensure no accidental damage to the underlying geosynthetics from equipment.

The leachate drainage aggregate shall be installed above the protection geotextile, over the base and abutting the lower side slopes of the proposed landfill cell. The drainage aggregate shall be a clean suitably sized granular material, sourced by the Principal.

The installation of the drainage aggregate shall be in accordance with the following;

- The drainage aggregate shall be constructed in one lift with a minimum thickness of 300mm across the entire base of the landfill cell, sloped with at least a 1% longitudinal gradient and 3% transverse gradient
- The drainage blanket shall be installed such that no wrinkles are developed in the underlying protection geotextile.
- A minimum 1m thickness of drainage blanket material shall be maintained between the protection geotextile and haulage vehicles (including waste vehicles).
- Road trucks will not be allowed to traffic on the aggregate due to potential bearing failure of the uniformly graded aggregate. Off-highway trucks are required to transport the aggregate into the cell works. Vehicle traffic shall not occur closer than 2m from a free edge of the aggregate layer. The wheel ruts shall not be deeper than 50mm and the trafficked surface shall be graded under controlled conditions to control the depth of the ruts.
- The Contractor shall take note that access ramps into the cell require relatively flat batters to prevent stability issues of the ramp slopes on the underlying geosynthetics layers. The Superintendent may impose measures to ensure the integrity of the liner and aggregate layer.
- The aggregate shall be placed by reversing the off-road truck over previously placed aggregate, and tipping on the previously placed material. Drainage aggregate shall be placed in a manner which does not result in excessive particle breakdown or crushing
- The blanket shall be spread using a 360° excavator, of maximum weight 12 tonnes, and graded using a low ground pressure dozer or by a method approved by the Superintendent which will be continually supervised such that any damage to the underlying material is identified and repaired accordingly. No slewing of the plant machinery placing the leachate collection gravel will be permitted during the works.
- The maximum allowable ground pressure for plant trafficking the 300mm thick drainage aggregate layer is 35 kPa

- The Contractor shall use a laser guided method, or similar approved to control the location of construction equipment blades relative to the surface of the underlying geosynthetics layers. The control shall ensure that the blades cannot move to within 200mm of the surface of the layers.
- The CQA Engineer shall be present on site to view the spreading of the aggregate. The Contractor shall take care to ensure the aggregate is worked around and under the leachate collection pipes to provide uniform support around the pipes. This is likely to require hand work. Where damage occurs to the underlying materials the CQA Engineer shall direct the Contractor on the actions required for repair.

The Contractor under the direction of the CQA Engineer will prove the leachate drainage blanket meets the 300mm minimum thickness by isoheight survey techniques.

Construction of the drainage aggregate shall be completed generally to the levels and dimensions as shown on the drawings. The following tolerances in finished dimensions shall not be exceeded:

- Thickness of drainage aggregate layer immediately following construction: -0/+30mm

7.4.1 Construction Quality Assurance

For aggregate drainage layers, the Contractor shall undertake the following;

- Field testing should be conducted during construction. The sampling should be overseen by the Construction Quality Assurance engineer. Note: Source testing before construction should confirm that the material can meet the hydraulic conductivity requirements and other properties specified.
- Testing should be conducted by an independent, NATA-accredited laboratory. The CQA Engineer should approve the chosen laboratory before construction starts.
- Testing of granular drainage materials should use methods specified in Australian Standard AS 1141 Methods for Sampling and Testing Aggregates and AS 1289 Method of testing soils for engineering purposes (Standards Australia, various dates) or equivalent methods in other recognised quality standards.
- The CQA Engineer should assess whether field testing additional to that stipulated by the designer is required in particular circumstances during construction.
- Granular drainage materials should be placed in a way that avoids damaging any underlying geosynthetic liner material.
- The contractor should minimise the entry of soil and rock particles into the drainage layer. These can increase the risk of clogging in the drainage layer. When waste is first placed over the layer, it should not damage or push up the separation geotextile layer and allow small particles into the drainage layer.
- Pipes should be laid on an even bed of material, be appropriately bedded and protected with surrounding material (at least 300mm over the crown of the pipe), and be properly joined, aligned and spaced.
- All site personnel should avoid driving heavy machinery over the drainage layer following placement.

7.5 Leachate Collection Pipework

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of HDPE pipework and fittings. The method statement shall be issued to the Superintendent for review and comment prior to delivery of the pipework to site.

7.5.1 Pipework Requirements

In accordance with Section 1.5 of the NSW EPA Guidelines 2016, the leachate collector pipes should:

- be high density polyethylene pipework at least 150 millimetres in internal diameter
- be perforated such that the size, frequency and layout of the perforations are sufficient to facilitate leachate inflow and extraction without clogging, prevent entry of drainage gravel, and maintain adequate pipe strength
- be strong enough to maintain performance under the maximum loads likely to be imposed in service, complying with the requirements of Australian Standard AS 2566.1-1998 Buried flexible pipelines – Structural design (Standards Australia, various dates)
- be joined by using techniques and materials recommended by the pipe manufacturer.
- be placed on the floor at intervals of not more than 25 metres (running the length of the cell), and be laid at gradients of at least 1% longitudinally into the sump and 3% in transverse directions.

The perforated main floor spine drain shall be minimum 250mm ID HDPE SDR11 pipework (typically PE100 PN16 SDR11 ID 256.3mm or OD 315mm). The perforated spur drain pipes shall be minimum 150mm ID HDPE SDR11 (typically PE100 PN16 SDR11 ID 162.5mm or OD 200mm). All leachate pipework shall be laid upon a minimum of 100mm of pipe bedding material and there shall be a minimum cover twice the diameter of the pipe of granular material, to the crown of the pipes, in accordance with the Drawings. Appropriate HDPE connectors will be required to connect the 250mm ID spine drain to the 150mm ID spur drain pipes.

The Contractor shall submit their proposals for all pipes and fittings to the Designer for approval and shall provide the CQA Engineer with copies of all pipe manufacturers' quality control documentation.

For pre-perforated pipework, perforations shall be not less than 10,000mm^2 of holes per metre length of pipe for the top 240^o of the pipe. The lower 120^o shall be solid to allow the flow of leachate to the extraction sump area as detailed within the Drawings. The perforations shall not reduce the pipe stiffness by more than 5%. Rectangular slots shall not be less than 5mm wide and 25mm long.

The Contractor shall submit calculations from the pipe manufacturer to demonstrate that the pipe meets the Specification requirements.

All pipe joins and junctions shall be manufactured from the same type of materials and display the same strength characteristics as the main leachate collection pipework. The pipe joins and junctions shall be installed in the cell, with all the pipe ends fitted with end caps manufactured of polyethylene.

The basal leachate collection spur pipework shall be connected to a side slope extraction riser on the eastern side wall of the proposed landfill. The extraction side riser will be a minimum 400mm ID HDPE SDR11 (typically PE100 PN16 SDR11 ID 406.8mm or OD 500mm . An angled collar and reducer will be required to connect the basal pipework to the side slope extraction riser.

The bottom 1m of the HDPE side slope riser pipe shall be perforated or slotted in the same arrangement as the basal spur pipework. For circular perforations the holes should not have a diameter greater than 10mm or less than 3mm and should not reduce the stiffness of the pipe by more than 5%. A temporary push-on cap shall be placed over the HDPE pipe.

The Contractor shall submit his proposals for all side slope leachate extraction riser pipework HDPE fittings to the Designer for approval.

7.5.2 Delivery, Storage and Handling

The pipework shall be delivered, handled and stored in accordance with the manufacturer's quality control documentation. The pipes should be stored on an area flat enough to accommodate the entire length of the pipes and in such a way so that they are not damaged or deformed. The pipes shall not be stacked higher than 1m.

7.5.3 Pipework Perforations

Where pipes are supplied un-perforated, the pipe installer shall perforate the leachate collection pipework by drilling holes into the pipe over the top 240^o of the pipe, the lower 120^o shall be solid to allow the flow of leachate to the extraction point.

The orientation of the holes shall be maintained during installation as far as practical at 45 degrees to the vertical. Care shall be taken when welding up the sections to orientate the sections to maintain the orientation of the holes in the pipeline.

All the swarf from drilling the perforations shall be removed prior to welding the pipes together.

7.5.4 Pipework Installation

A leachate collection pipework system incorporating perforated HDPE pipes shall be installed across the base feeding to a sump in accordance with the Drawings.

The Contractor shall prevent any damage from occurring to the underlying geotextile during pipe installation.

The installation and welding of HDPE pipes shall only be undertaken by skilled and experienced personnel. The Contractor shall supply, prior to commencement of the works, a summary of experience or that of their subcontractor with the materials and shall be included as part of the final construction quality assurance validation report.

An end cap of similar strength as the pipe shall be installed on the upstream end of the pipes.

The Contractor shall ensure by survey that the leachate collection pipes are placed in accordance with the drawings.

7.5.5 Pipework Welding

All pipework will be butt fusion (full face fusion) welded (bead free technique) or connected using electro-fusion (EF) couplings. The Contractor shall supply the CQA Engineer with the following welding information for each welded joint:

- Date and time of weld
- Weld number
- Operator
- Heater temperature, heat soak time
- Bead pressure, fusion pressure
- Actual and target cooling times.

The pipes shall be welded adjacent to the cell ready to be rolled or manually handled into place by hand and winch. The leachate pipes shall not be welded in-situ.

7.6 Sign Off

The aggregate drainage and pipework shall be accepted by the Principal when the following conditions are met:

- The CQA Engineer is satisfied that aggregate drainage and pipework/connections meets the Specification requirements.
- Pipework has been handled and installed in accordance with the Specification and manufacturers recommendations.
- All test results have been received by the CQA Engineer and verified as having met the requirements of the Specification.
- Survey plans are received demonstrating compliant aggregate thicknesses and pipework spacing.
- Ensure the blanket be installed to a minimum thickness of 300mm and extends across the entire base of the landfill, sloped with at least a 1% longitudinal gradient and 3% transverse gradient;
- The Superintendent has inspected and approved the finished aggregate drainage hold point.

8 ELECTRICAL LEAK DETECTION SURVEY

In accordance with Section 11.1(d) of the NSW EPA Guidelines 2016, an electrical leak detection survey is required to be undertaken. Details from the Guidelines are as follows:

An electrical leak detection survey (also called an electrical liner integrity survey) should be carried out on geomembrane liners before and after the overlying drainage material has been placed. Damage can occur both during installation of the geomembrane and during placement of the materials on top of it – surveys at the two stages can assess this. Surveys shall be undertaken on Cells 1 & 2 as well as on the proposed leachate dam. The 'before' survey only shall be undertaken on the leachate dam.

Such surveys use the fact that most geomembrane materials are electrically non-conductive. Where there are no defects, electrical current cannot flow through the geomembrane. The various methods locate spots where, under an applied voltage, electrical current is able to flow through holes and other breaches in the geomembrane. There must be conductive material above and below the geomembrane. The power source is grounded to the underlying material. Water is typically added to the overlying material to provide a conductive medium that can carry current through holes to the conductive material below.

The survey area must be electrically isolated from surrounding ground and structures to prevent the formation of competing electrical pathways between the upper and lower conductive materials.

A compacted clay liner below a geomembrane usually has suitable conductivity. However, other types of sub-grade soils or geosynthetic clay liners below a geomembrane must have sufficient moisture content to be adequately conductive of electricity. In these cases, the methods will not work if the underlying material is too dry. Sometimes copper wiring must be installed to provide a lower conductive pathway. This may need to be considered at the design stage.

The methods and instruments that can be used in each case depend on whether the geomembrane is covered or uncovered. Methods for surveying uncovered (bare) geomembranes include the water puddle and water lance methods. Water is applied to the surface of the geomembrane to create an electrically conductive layer able to form a bridge through holes to the lower conductive material when a voltage is applied. There must be good contact between the geomembrane and underlying material, otherwise holes may be missed. An emerging method, not involving water, applies a high voltage above the geomembrane to create an electric arc where there are holes.

For covered geomembranes, a dipole method is used in which a positive electrode is placed in the cover material, the power source is connected to the material beneath the geomembrane, and measurements of voltage potential are taken with a dipole probe in a grid pattern across the surface. Waves or spikes in voltage potential indicate the presence of a hole through which current is leaking. As with other methods, the cover material may need to be suitably moistened.

The methods for testing covered geomembranes are less sensitive than the methods that can be used in uncovered situations. The dipole method will detect only larger holes (typically about 6.4 millimetres in diameter when the cover material is 0.6 metres deep). The test methods for uncovered geomembranes are typically sensitive to holes of about 1 millimetre diameter. Standard test methods prescribe applicable sensitivities and procedures for sensitivity testing and calibration.

For detailed guidance on these issues and on the various methods see ASTM D6747-15 Standard Guide for Selection of Techniques for Electrical Leak Location of Leaks in Geomembranes (ASTM International, 2015) and Electrical Leak Location General Guide (TRI Environmental Inc., 2014) or equivalent standards.

9 STATEMENT OF COMPLIANCE

This document has been prepared by InSitu Advisory Pty Ltd with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of MH Earthmoving Pty Ltd and any party associated with the proposed development and approval. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from InSitu Advisory Pty Ltd.

This report is not a detailed design or Specification and should not be used as such, or for any purpose other than its intended use. This report must be read in full and in conjunction with the CQA Plan, specialist studies and associated drawings and any other relevant documentation.

InSitu Advisory Pty Ltd is a Member of the APIV Limitation of Liability Scheme approved under Professional Standards Legislation.

InSitu Advisory Pty Ltd disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

10 REFERENCES

- Environmental Guidelines Solid Waste Landfills, Second Edition, NSW EPA, dated April 2016;
- GRI – GM13 Standard Specification, Revision 14, Geosynthetic Research Institute, January 2016;

DRAWINGS / FIGURES

APPENDIX A

SITE BOREHOLE INVESTIGATION DATA
D.M McMAHON PTY LTD 2019

DRILLING 18/2/19

Disclaimer: This report has been generated by various sources and is provided for information purposes only. Spatial Services does not warrant or represent that the information is free from errors or omission, or that it is exhaustive. Spatial Services gives no warranty in relation to the information, especially material supplied by third parties. Spatial Services accepts no liability for loss, damage, or costs that you may incur relating to any use or reliance upon the information in this report.

McMahon EARTH SCIENCE

Job No:	5803	**Landform:**	Pit floor
Client:	MH Earthmoving Pty Ltd	**Slope:**	Level
Site:	Bangus Quarry	**Vegetation/Surface:**	Rock
Date:	18/02/2019	**Logged By:**	DM

Sheet: 'Geotech Field Sheet_rev2'

Sampling Method: AS1289.1.2.1-1998: cl. [ ] 6.5.1 - Hand Excavated [ ] 6.5.2 - Hand Auger [ ] 6.5.3 - Power Auger [ ] 6.5.4 - Machine Excavated Other: 87mm DTH Hammer

Site Identity	Sample	Co-ordinates MGA GDA94 z55	Depth to Top of Layer (m)	Depth to Bottom of Layer (m)	Classification (AS1726:2017 Table 20)	Name (BLOCK LETTERS)	Grain Size (Fine / Coarse)	Primary Colour	Weathering Colour	Plasticity	Strength	Relative Density (Non-cohesive)	Moisture	Origin	Comments (Coarse Fragments, Size, %, Structure (Zoning, Defects, Cementing etc.))
1	-	589132E	0.0	3.6	XM	Siltstone	Fine	Y	R	Low	VL	-	D	Silurian	-
	-	6113443N	3.6	7.2	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
2	-	589104E	0.0	3.6	XM	Siltstone	Fine	Y	R	Low	VL	-	D	Silurian	Some rounded fragments
	-	6113494N	3.6	7.2	HW	Siltstone	Fine	G	-	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	-	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
3	-	589049E	0.0	3.6	XM	Siltstone	Fine	Y	R	Low	VL	-	D	Silurian	-
	-	6113449N	3.6	7.2	XM	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-

McMahon EARTH SCIENCE

Job No:	5803	**Landform:**	Pit floor
Client:	MH Earthmoving Pty Ltd	**Slope:**	Level
Site:	Bangus Quarry	**Vegetation/Surface:**	Rock
Date:	18/02/2019	**Logged By:**	DM

Sheet: 'Geotech Field Sheet_rev2'

Sampling Method: AS1289.1.2.1-1998: cl. [ ] 6.5.1 - Hand Excavated [ ] 6.5.2 - Hand Auger [ ] 6.5.3 - Power Auger [ ] 6.5.4 - Machine Excavated Other: 87mm DTH Hammer

Site Identity	Sample	Co-ordinates MGA GDA94 z55	Depth to Top of Layer (m)	Depth to Bottom of Layer (m)	Classification (AS1726:2017 Table 20)	Name (BLOCK LETTERS)	Grain Size (Fine / Coarse)	Primary Colour	Weathering Colour	Plasticity	Strength	Relative Density (Non-cohesive)	Moisture	Origin	Comments (Coarse Fragments, Size, %, Structure (Zoning, Defects, Cementing etc.))
4	-	589097E	0.0	3.6	ML	CLAY	Fine	R	Y	Low	VL	-	D	Residual	-
	-	6113425N	3.6	7.2	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
5	-	589094E	0.0	3.6	ML	CLAY	Fine	R	Y	Low	VL	-	D	Residual	-
	-	6113458N	3.6	7.2	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-

APPENDIX B

ON-SITE CLAY SOURCE EVALUATION DATA

DM McMahon Pty Ltd
PO Box 6118
WAGGA WAGGA NSW 2650
Ph: 0269 310 510

TEST REPORT
FALLING HEAD PERMEABILITY
AS TEST METHOD AS 1289.6.7.2

CLIENT: Martin Hay Earthmoving Pty Ltd
JOB DESCRIPTION: Site Investigation
LOCATION: Tumblong Reserve Road, Tumblong

PAGE: 1
OF: 1
SUBMITTED BY: D. McMahon
DATE SUBMITTED: 14/02/19
NO OF SAMPLES: 1
TEST METHODS: AS 1289.6.7.2
AS1289.5.1.1
AS1289.2.1.1
JOB NUMBER: 5803

MATERIAL TYPE: Stockpile - Silty Sandy Clay
SURCHARGES ADDED: 2.65kg (1.0L mould)
PRESSURE APPLIED: 3kPa
NOMINAL SIEVE SIZE: 9.5mm
% RETAINED SIEVE: Nil
COMPACTION METHOD: STANDARD

Sample No.	Maximum Dry Density - MDD (t/m3)	Optimum Moisture - OMC (%)	Dry Density of Specimen (%)	Moisture Moulding (%)	% of OMC	% of MDD	Permeability m/sec
1	2.041	9.6	2.136	9.6	101	105	$3.54x10^{-8}$
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Number: 3349

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REMARKS:

APPROVED SIGNATORY: A. Rudd DATE: 1/03/2019

DM McMahon Pty Ltd
PO Box 6118
WAGGA WAGGA NSW 2650
Ph: 0269 310 510

SUBMITTED BY: JH
DATE SUBMITTED: 16/04/19
NO OF SAMPLES: 3
SAMPLING METHOD: AS1141.3.1
CLAUSE: 3.8
SPECIFICATIONS: *
PREPARATION METHOD: *

TEST REPORT

AS 1289.3.6.3

Particle size distribution of a soil - Standard method of fine analysis using a hydrometer

CLIENT: MH Earthmoving Pty Ltd
JOB DESCRIPTION: Bangus Clay

MATERIAL SOURCE: Stockpile - Bangus Quarry
PROPOSED USE: Clay Liner
MATERIAL TYPE: Red Clay

JOB NO.: 5981

Particle Size Distribution by Hydrometer

Sample ID: 5981/1
Type of Hydrometer: ASTM E100 (g/L)
Method of dispersion: Mechanical
Soil Particle Density: 2.66 g/cm^3

Particle Size	Percent Passing
2.36 mm	100.0 %
600 µm	80.6 %
300 µm	59.7 %
212 µm	48.9 %
75 µm	29.1 %
62.4 µm	28.5 %
44.4 µm	27.8 %
31.6 µm	27.2 %
22.4 µm	26.9 %
16.0 µm	26.0 %
11.8 µm	25.4 %
8.4 µm	24.8 %
5.9 µm	23.5 %
4.2 µm	22.9 %
3.0 µm	22.3 %
2.1 µm	21.0 %
1.3 µm	20.4 %
1.1 µm	19.8 %
0.9 µm	19.8 %
0.8 µm	19.2 %

Comments: *NATA accreditation not held for AS 1289.3.6.3

APPROVED SIGNATORY: A. Rudd

DATE: 13/05/2019

DM McMahon Pty Ltd
PO Box 6118
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Ph: 0269 310 510

SUBMITTED BY: JH
DATE SUBMITTED: 16/04/19
NO OF SAMPLES: 3
SAMPLING METHOD: AS1141.3.1
CLAUSE: 3.8
SPECIFICATIONS: *
PREPARATION METHOD: *

TEST REPORT

AS 1289.3.6.3

Particle size distribution of a soil - Standard method of fine analysis using a hydrometer

CLIENT: MH Earthmoving Pty Ltd
JOB DESCRIPTION: Bangus Clay

MATERIAL SOURCE: Stockpile - Bangus Quarry
PROPOSED USE: Clay Liner
MATERIAL TYPE: Red Clay

JOB NO.: 5981

Particle Size Distribution by Hydrometer

Sample ID: 5981/2
Type of Hydrometer: ASTM E100 (g/L)
Method of dispersion: Mechanical
Soil Particle Density: 2.65 g/cm^3

Particle Size	Percent Passing
2.36 mm	100.0 %
600 µm	88.7 %
300 µm	75.2 %
212 µm	67.9 %
75 µm	53.0 %
50.4 µm	46.4 %
36.9 µm	43.9 %
26.5 µm	42.6 %
19.1 µm	41.3 %
13.7 µm	40.0 %
10.2 µm	38.8 %
7.3 µm	38.1 %
5.1 µm	36.9 %
3.7 µm	36.2 %
2.6 µm	35.0 %
1.9 µm	34.3 %
1.1 µm	33.7 %
1.0 µm	33.0 %
0.8 µm	33.0 %
0.8 µm	32.4 %

Comments: *NATA accreditation not held for AS 1289.3.6.3

APPROVED SIGNATORY: A. Rudd

DATE: 13/05/2019

DM McMahon Pty Ltd
PO Box 6118
WAGGA WAGGA NSW 2650
Ph: 0269 310 510

PAGE: 5
OF: 5
SUBMITTED BY: JH
DATE SUBMITTED: 16/04/19
NO OF SAMPLES: 3
SAMPLING METHOD: AS1141.3.1
CLAUSE: 3.8
SPECIFICATIONS: *
PREPARATION METHOD: *

TEST REPORT

AS 1289.3.6.3

Particle size distribution of a soil - Standard method of fine analysis using a hydrometer

CLIENT: MH Earthmoving Pty Ltd
JOB DESCRIPTION: Bangus Clay
MATERIAL SOURCE: Stockpile - Bangus Quarry
PROPOSED USE: Clay Liner
MATERIAL TYPE: Red Clay

JOB NO.: 5981

Particle Size Distribution by Hydrometer

Sample ID: 5981/3
Type of Hydrometer: ASTM E100 (g/L)
Method of dispersion: Mechanical
Soil Particle Density: 2.65 g/cm^3

Particle Size	Percent Passing
2.36 mm	100.0 %
600 µm	87.6 %
300 µm	76.1 %
212 µm	69.1 %
75 µm	48.1 %
51.3 µm	44.5 %
36.9 µm	43.3 %
26.3 µm	42.7 %
19.1 µm	40.8 %
13.6 µm	40.2 %
10.1 µm	38.9 %
7.2 µm	38.3 %
5.1 µm	37.0 %
3.6 µm	36.4 %
2.6 µm	35.8 %
1.8 µm	35.1 %
1.1 µm	34.5 %
0.9 µm	33.9 %
0.8 µm	33.9 %
0.8 µm	33.9 %

Comments: *NATA accreditation not held for AS 1289.3.6.3

APPROVED SIGNATORY: A. Rudd

DATE: 13/05/2019

DM McMahon Pty Ltd
PO Box 6118
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Ph: 0269 310 510

SUBMITTED BY: JH
DATE SUBMITTED: 16/04/19
NO OF SAMPLES: 3
SAMPLING METHOD: AS1141.3.1
CLAUSE: 3.8
SPECIFICATIONS: *
PREPARATION METHOD: *

TEST REPORT

PAVEMENT MATERIALS, FILLS, SUBGRADE AND SOILS

CLIENT: MH Earthmoving Pty Ltd
JOB DESCRIPTION: Bangus Clay

MATERIAL SOURCE: Stockpile - Bangus Quarry
PROPOSED USE: Clay Liner
MATERIAL TYPE: Red Clay

JOB NO.: 5981

				SAMPLE NUMBER:	1	2	3	*	*
				SITE OR CHAINAGE (m):	Stockpile	Stockpile	Stockpile	*	*
				DEPTHS BETWEEN WHICH SAMPLES TAKEN (m):	N/A	N/A	N/A	*	*
			SPECIFIED LIMITS LISTED BELOW FOR:	*	*	*	*	*	*	*
TESTS			PRETREATMENT:	*	*	Nil	Nil	Nil	*	*
T106			PASS 75.0mm SIEVE %	*	*	100	100	100	*	*
			PASS 53.0mm SIEVE %	*	*	100	100	100	*	*
			PASS 37.5mm SIEVE %	*	*	100	100	100	*	*
			PASS 26.5mm SIEVE %	*	*	100	100	100	*	*
			PASS 19.0mm SIEVE %	*	*	96	94	98	*	*
			PASS 13.2mm SIEVE %	*	*	95	93	97	*	*
			PASS 9.50mm SIEVE %	*	*	93	92	96	*	*
			PASS 6.70mm SIEVE %	*	*	87	92	85	*	*
			PASS 4.75mm SIEVE %	*	*	80	90	79	*	*
			PASS 2.36mm SIEVE %	*	*	75	86	72	*	*
T107	WHOLE		PASS 425µm SIEVE %	*	*	63	78	68	*	*
	SAMPLE		PASS 75µm SIEVE %	*	*	46	62	57	*	*
			LESS THAN 13.5µm %	*	*	26.7	37.0	36.8	*	*
RATIOS	A -		PASS 425µm %	*	*	84	91	94	*	*
	B -		PASS 75/425 µm %	*	*	73	79	84	*	*
	C -		BELOW 13.5/75µm %	*	*	58	60	65	*	*
AS1289.3.1.2			LIQUID LIMIT %	*	*	38	51	55	*	*
AS1289.3.2.1			PLASTIC LIMIT %	*	*	17	15	15	*	*
AS1289.3.3.1			PLASTICITY INDEX %	*	*	21	36	40	*	*
T113			LINEAR SHRINKAGE %	*	*	*	*	*	*	*
T111			MAX. DRY DENSITY t/m³	*	*	1.815	1.702	1.607	*	*
			OPTIMUM MOISTURE CONTENT %	*	*	14.8	19.0	15.6	*	*
AS1289.3.5.1 *	AVERAGE APPARENT PARTICLE DENSITY (g/cm^3)		PASS 2.36mm	*	*	2.66	2.65	2.65	*	*
			RET. 2.36mm	*	*	2.65	2.66	2.66	*	*
			TEMPERATURE OF TEST (°C)	*	*	19	17	20	*	*
			SOIL PARTICLE DENSITY (ρ_{st}) (g/cm^3)	*	*	2.66	2.65	2.65	*	*
AS1289.2.1.1			FIELD MOISTURE CONTENT %	*	*	10.2	13.9	9.6	*	*

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Number: 3349

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*NATA accreditation not held for AS 1289.3.5.1.

All samples are oven dried and dry sieved preparation unless otherwise stated

APPROVED SIGNATORY: A. Rudd

DATE: 10/05/2019

DM McMahon Pty Ltd
PO Box 6118
WAGGAWAGGA NSW 2650
Ph: 0269 310 510

TEST REPORT
FALLING HEAD PERMEABILITY
AS TEST METHOD AS 1289.6.7.2

CLIENT: MH Earthmoving Pty Ltd
JOB DESCRIPTION: Bangus Clay
LOCATION: Bangus Quarry

PAGE: 2
OF: 3
SUBMITTED BY: JH
DATE SUBMITTED: 16/04/19
NO OF SAMPLES: 2
TEST METHODS: AS 1289.6.7.2
RMS T111
RMS T120
JOB NUMBER: 5981

MATERIAL TYPE: Red Clay
SURCHARGES ADDED: 2.65kg (1.0L mould)
PRESSURE APPLIED: 3kPa
NOMINAL SIEVE SIZE: 9.5mm
% RETAINED SIEVE: Nil
COMPACTION METHOD: STANDARD

Sample No.	Maximum Dry Density - MDD (t/m^3)	Optimum Moisture - OMC (%)	Dry Density of Specimen (%)	Moisture Moulding (%)	% of OMC	% of MDD	Permeability m/sec
1	1.815	14.8	1.829	14.9	101	101	9.23×10^{-10}
2	1.702	19.0	1.795	19.7	104	106	8.06×10^{-10}
3	1.607	15.6	1.831	15.6	100	114	1.55×10^{-09}
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*

NATA
ACCREDITED FOR TECHNICAL COMPETENCE
Number: 3349

Accredited for compliance with ISO/IEC 17025. The results of these tests, calibrations and/or measurement included in this document are traceable to Australian/National Standards. This document shall not be reproduced except in full.

REMARKS:

APPROVED SIGNATORY: A. Rudd

DATE: 10/05/2019

DM McMahon Pty Ltd
PO Box 6118
WAGGA WAGGA NSW 2650
Ph: 0269 310 510

SUBMITTED BY: JH
DATE SUBMITTED: 16/04/19
NO OF SAMPLES: 3
SAMPLING METHOD: AS1141.3.1
CLAUSE: 3.8
SPECIFICATIONS: *
PREPARATION METHOD: *

TEST REPORT

PAVEMENT MATERIALS, FILLS, SUBGRADE AND SOILS

CLIENT: MH Earthmoving Pty Ltd
JOB DESCRIPTION: Bangus Clay

MATERIAL SOURCE: Stockpile - Bangus Quarry
PROPOSED USE: Clay Liner
MATERIAL TYPE: Red Clay

JOB NO.: 5981

				SAMPLE NUMBER:	1	2	3	*	*
				SITE OR CHAINAGE (m):	Stockpile	Stockpile	Stockpile	*	*
				DEPTHS BETWEEN WHICH SAMPLES TAKEN (m):	N/A	N/A	N/A	*	*
			SPECIFIED LIMITS LISTED BELOW FOR:	*	*	*	*	*	*	*
TESTS			PRETREATMENT:	*	*	Nil	Nil	Nil	*	*
T106			PASS 75.0mm SIEVE %	*	*	100	100	100	*	*
			PASS 53.0mm SIEVE %	*	*	100	100	100	*	*
			PASS 37.5mm SIEVE %	*	*	100	100	100	*	*
			PASS 26.5mm SIEVE %	*	*	100	100	100	*	*
			PASS 19.0mm SIEVE %	*	*	96	94	98	*	*
			PASS 13.2mm SIEVE %	*	*	95	93	97	*	*
			PASS 9.50mm SIEVE %	*	*	93	92	96	*	*
			PASS 6.70mm SIEVE %	*	*	87	92	85	*	*
			PASS 4.75mm SIEVE %	*	*	80	90	79	*	*
			PASS 2.36mm SIEVE %	*	*	75	86	72	*	*
T107	WHOLE		PASS 425µm SIEVE %	*	*	63	78	68	*	*
	SAMPLE		PASS 75µm SIEVE %	*	*	46	62	57	*	*
			LESS THAN 13.5µm %	*	*	26.7	37.0	36.8	*	*
RATIOS	A -		PASS 425µm %	*	*	84	91	94	*	*
	B -		PASS 75/425 µm %	*	*	73	79	84	*	*
	C -		BELOW 13.5/75µm %	*	*	58	60	65	*	*
AS1289.3.1.2			LIQUID LIMIT %	*	*	38	51	55	*	*
AS1289.3.2.1			PLASTIC LIMIT %	*	*	17	15	15	*	*
AS1289.3.3.1			PLASTICITY INDEX %	*	*	21	36	40	*	*
T113			LINEAR SHRINKAGE %	*	*	*	*	*	*	*
T111			MAX. DRY DENSITY t/m³	*	*	1.815	1.702	1.607	*	*
			OPTIMUM MOISTURE CONTENT %	*	*	14.8	19.0	15.6	*	*
AS1289.3.5.1 *	AVERAGE APPARENT PARTICLE DENSITY (g/cm^3)		PASS 2.36mm	*	*	2.66	2.65	2.65	*	*
			RET. 2.36mm	*	*	2.65	2.66	2.66	*	*
			TEMPERATURE OF TEST (°C)	*	*	19	17	20	*	*
			SOIL PARTICLE DENSITY (ρ_{st}) (g/cm^3)	*	*	2.66	2.65	2.65	*	*
AS1289.2.1.1			FIELD MOISTURE CONTENT %	*	*	10.2	13.9	9.6	*	*

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*NATA accreditation not held for AS 1289.3.5.1.

All samples are oven dried and dry sieved preparation unless otherwise stated

APPROVED SIGNATORY: A. Rudd

DATE: 10/05/2019

Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

DM McMahon Ptv Ltd
PO BOX 6118

WAGGA WAGGA
NSW 2650

Report Print Date: 29/04/2019
Agent/Dealer:
Advisor/Contact: D M MCMAHON PTY LTD
Phone: 02 6931 0510
Purchase Order No: 5981

Grower Name : D M MCMAHON PTY LTD
Sample No: 022019393
Paddock Name: BANGUS QUARRY
Sample Name: 5981-1
Sample Depth (cm): 0 **To** 10

Nearest Town: WAGGA NORTH
Test Code: E11
Sample Type: Soil
Sampling Date: 26/04/2019

Analyte / Assay	Units	Value
pH (1:5 Water)		5.2
pH (1:5 CaCl2)		4.0
Electrical Conductivity (1:5 water)	dS/m	0.03
Chloride	mg/kg	<10
Nitrate Nitrogen	mg/kg	4
Ammonium Nitrogen	mg/kg	1
Phosphorus (Colwell)	mg/kg	<5
Phosphorus Buffer Index		230
Sulphur (KCl40)	mg/kg	3
Cation Exch. Cap. (CEC)	cmol(+)/kg	7.2
Calcium (Amm-acet.)	cmol(+)/kg	0.3
Magnesium (Amm-acet.)	cmol(+)/kg	2.0
Sodium (Amm-acet.)	cmol(+)/kg	0.09
Potassium (Amm-acet.)	cmol(+)/kg	0.36
Available Potassium	mg/kg	140
Aluminium (KCl)	cmol(+)/kg	4.5
Aluminium % of Cations	%	62.0
Calcium % of Cations	%	3.7
Magnesium % of Cations	%	27.0
Sodium % of Cations (ESP)	%	1.30
Potassium % of Cations	%	5.10
Calcium/Magnesium Ratio		0.1

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
Tel: 1800 803 453
Certificate of Analysis is available upon request.
Email: lab.feedback@incitecpivot.com.au

Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

Grower Name :	D M MCMAHON PTY LTD	**Nearest Town:**	WAGGA NORTH
Sample No:	022019393	**Test Code:**	E11
Paddock Name:	BANGUS QUARRY	**Sample Type:**	Soil
Sample Name:	5981-1	**Sampling Date:**	26/04/2019
Sample Depth (cm):	0 **To** 10		

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
* One or more components of this test are below their detection limit. The value used is indicative only.

Disclaimer: *Laboratory analyses and fertiliser recommendations are made in good faith, based on the best technical information available as at the date of this report. Incitec Pivot Limited, its officers, employees, consultants, Agents and Dealers do not accept any liability whatsoever arising from or in connection with the analytical results, interpretations and recommendations provided, and the client takes the analytical results, interpretations and recommendations on these terms. In respect of liability which cannot be excluded by law, Incitec Pivot's liability is restricted to the re-supply of the laboratory analysis or the cost of having the analysis re-supplied.*

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Nutrient Advantage Advice® Nutrient Report

DM McMahon Ptv Ltd
PO BOX 6118

WAGGA WAGGA
NSW 2650

Report Print Date: 29/04/2019
Agent/Dealer:
Advisor/Contact: D M MCMAHON PTY LTD
Phone: 02 6931 0510
Purchase Order No: 5981

Grower Name : D M MCMAHON PTY LTD
Sample No: 022019394
Paddock Name: BANGUS QUARRY
Sample Name: 5981-2
Sample Depth (cm): 0 **To** 10

Nearest Town: WAGGA NORTH
Test Code: E11
Sample Type: Soil
Sampling Date: 26/04/2019

Analyte / Assay	Units	Value
pH (1:5 Water)		5.3
pH (1:5 CaCl2)		4.0
Electrical Conductivity (1:5 water)	dS/m	0.05
Chloride	mg/kg	21
Nitrate Nitrogen	mg/kg	8
Ammonium Nitrogen	mg/kg	1
Phosphorus (Colwell)	mg/kg	<5
Phosphorus Buffer Index		290
Sulphur (KCl40)	mg/kg	2
Cation Exch. Cap. (CEC)	cmol(+)/kg	11.0
Calcium (Amm-acet.)	cmol(+)/kg	0.1
Magnesium (Amm-acet.)	cmol(+)/kg	5.7
Sodium (Amm-acet.)	cmol(+)/kg	0.49
Potassium (Amm-acet.)	cmol(+)/kg	0.48
Available Potassium	mg/kg	190
Aluminium (KCl)	cmol(+)/kg	4.2
Aluminium % of Cations	%	38.0
Calcium % of Cations	%	1.1
Magnesium % of Cations	%	52.0
Sodium % of Cations (ESP)	%	4.40
Potassium % of Cations	%	4.30
Calcium/Magnesium Ratio		0.0

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Nutrient Advantage Advice® Nutrient Report

Grower Name :	D M MCMAHON PTY LTD	**Nearest Town:**	WAGGA NORTH
Sample No:	022019394	**Test Code:**	E11
Paddock Name:	BANGUS QUARRY	**Sample Type:**	Soil
Sample Name:	5981-2	**Sampling Date:**	26/04/2019
Sample Depth (cm):	0 **To** 10		

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
* One or more components of this test are below their detection limit. The value used is indicative only.

Disclaimer: *Laboratory analyses and fertiliser recommendations are made in good faith, based on the best technical information available as at the date of this report. Incitec Pivot Limited, its officers, employees, consultants, Agents and Dealers do not accept any liability whatsoever arising from or in connection with the analytical results, interpretations and recommendations provided, and the client takes the analytical results, interpretations and recommendations on these terms. In respect of liability which cannot be excluded by law, Incitec Pivot's liability is restricted to the re-supply of the laboratory analysis or the cost of having the analysis re-supplied.*

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Nutrient Advantage Advice® Nutrient Report

DM McMahon Ptv Ltd
PO BOX 6118

WAGGA WAGGA
NSW 2650

Report Print Date: 29/04/2019
Agent/Dealer:
Advisor/Contact: D M MCMAHON PTY LTD
Phone: 02 6931 0510
Purchase Order No: 5981

Grower Name : D M MCMAHON PTY LTD
Sample No: 022019395
Paddock Name: BANGUS QUARRY
Sample Name: 5981-3
Sample Depth (cm): 0 **To** 10

Nearest Town: WAGGA NORTH
Test Code: E11
Sample Type: Soil
Sampling Date: 26/04/2019

Analyte / Assay	Units	Value
pH (1:5 Water)		5.2
pH (1:5 CaCl2)		4.1
Electrical Conductivity (1:5 water)	dS/m	0.04
Chloride	mg/kg	17
Nitrate Nitrogen	mg/kg	4
Ammonium Nitrogen	mg/kg	3
Phosphorus (Colwell)	mg/kg	<5
Phosphorus Buffer Index		490
Sulphur (KCl40)	mg/kg	3
Cation Exch. Cap. (CEC)	cmol(+)/kg	13.4
Calcium (Amm-acet.)	cmol(+)/kg	0.1
Magnesium (Amm-acet.)	cmol(+)/kg	6.5
Sodium (Amm-acet.)	cmol(+)/kg	0.30
Potassium (Amm-acet.)	cmol(+)/kg	0.81
Available Potassium	mg/kg	320
Aluminium (KCl)	cmol(+)/kg	5.7
Aluminium % of Cations	%	43.0
Calcium % of Cations	%	0.6
Magnesium % of Cations	%	49.0
Sodium % of Cations (ESP)	%	2.30
Potassium % of Cations	%	6.00
Calcium/Magnesium Ratio		0.0

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Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

Grower Name :	D M MCMAHON PTY LTD	**Nearest Town:**	WAGGA NORTH
Sample No:	022019395	**Test Code:**	E11
Paddock Name:	BANGUS QUARRY	**Sample Type:**	Soil
Sample Name:	5981-3	**Sampling Date:**	26/04/2019
Sample Depth (cm):	0 **To** 10		

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
* One or more components of this test are below their detection limit. The value used is indicative only.

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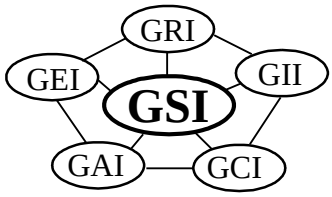
APPENDIX C

GRI GM13 HDPE GEOMEMBRANE REQUIREMENTS

Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441



Revision 14: January 6, 2016
Revision schedule on pg. 11

GRI - GM13 Standard Specification*

Standard Specification for

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

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

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

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

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

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

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

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

2. Referenced Documents

2.1 ASTM Standards

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

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

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

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

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

Nominal - Representative value of a measurable property determined under a set of conditions, by which a product may be described. Abbreviated as nom. in Tables 1 and 2.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

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

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

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

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

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

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

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

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

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

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

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

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

6. Workmanship and Appearance

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

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

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

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

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

9. Packaging and Marketing

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

10. Certification

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

ENGLISH UNITS

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

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

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.

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

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

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

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

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

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

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

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

SI (METRIC) UNITS

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

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

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

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

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

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

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

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

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

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

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

ENGLISH UNITS

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

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

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

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(3) SP-NCTL per ASTM D5397 Appendix, is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

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

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

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

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

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

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

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

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

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

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

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

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

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

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

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

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

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

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

Adoption and Revision Schedule
for
HDPE Specification per GRI-GM13

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

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
Revision 7:	February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
Revision 8:	Removed recommended warranty from specification.
Revision 9:	June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
Revision 10	April 11, 2011: Added alternative carbon black content test methods
Revision 11	December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
Revision 12	November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 13	November 4, 2015: Removed Footnote (1) on asperity height from tables.
Revision 14	January 6, 2016: Removed Trouser Tear from Note 5.

InSitu Advisory

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