

ANNEXURE C- CQA DOCUMENT



**CONSTRUCTION QUALITY
ASSURANCE (CQA) PLAN**

FOR

**LAFARGE LICHTENBERG POLLUTION
CONTROL DAMS**

DECEMBER 2022

REVISION 0



Prepared by:

JG AFRIKA (PTY) LTD

Email: norrisj@jgafrika.com

Project Director: J. Norris

VERIFICATION PAGE				Qual-frm-026
				Rev 14
TITLE: CONSTRUCTION QUALITY ASSURANCE DOCUMENT FOR LAFARGE LICHTENBURG POLLUTION CONTROL DAMS				
JGA REF. NO. 5707	DATE: 14/12/2022		REPORT STATUS For DWS Submission	
CARRIED OUT BY: JG AFRIKA (PTY) LTD PO Box 794 Hilton 3245 Tel.: +27 33 343 6700 Email: norrisj@jgafrika.com		COMMISSIONED BY: Lafarge Industries South Africa (PTY) LTD LICHTENBURG 1 Manana Road Industrial Site 2740 Tel: +27 21 633 3011 Email: Uneysa.taljard@lafarge.com		
AUTHORS Jan Norris, Mukovhe Muvhali		CLIENT CONTACT PERSON Uneysa Taljard		
SYNOPSIS Construction Quality Assurance Document for Lafarge Lichtenburg Pollution Control Dams				
KEY WORDS: GCL, CCL, geomembrane, geosynthetics, geotextile, subsoil drain, contaminated stormwater, GNR 636, DWS				
© COPYRIGHT: JG Afrika (Pty) Ltd.				
QUALITY VERIFICATION				
This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2015 which has been independently certified by DEKRA Certification under certificate number 90906882				
Verification	Capacity	Name	Signature	Date
By Author	Engineer	M Muvhali		14/12/2022
Checked by:	Director	J Norris PrEng		14/12/2022
Authorised by:	Director	J Norris PrEng		14/12/2022
Filename:	W:\Hydro\JGA\5707 - Lafarge Lichtenburg Specialist WULA Studies And PCD Design (PH)\02 Calculations And Assessments\PCD Liner\DWS Checklist\Annexure C - CQA\Lafarge PCD CQA.Docx			

TABLE OF CONTENTS

1	INTRODUCTION	1
1.1	Quality Assurance (QA)	1
1.2	Quality Control (QC)	1
2	PARTIES INVOLVED WITH CONSTRUCTION ASSURANCE	2
2.1	EMPLOYER	2
2.2	CONSTRUCTION MANAGER	2
2.3	DESIGN ENGINEER.....	2
2.4	EMPLOYER's AGENT	2
2.5	CONSTRUCTION QUALITY ASSURANCE OFFICER (CQAO)	3
2.6	MAIN CONTRACTOR.....	3
2.7	Civil Contractor.....	3
2.8	Geosynthetic Membrane (GSM) Manufacturer	4
2.9	Transporter.....	4
2.10	Geosynthetic Membrane (GSM) Installer.....	4
2.11	Installation Supervisor (superintendent).....	4
2.12	Independent Construction Quality Assurance (CQA) Laboratory.....	4
3	MEETINGS	6
3.1	PRE-CONSTRUCTION MEETINGS	6
3.2	PROGRESS MEETINGS.....	6
3.3	RESOLUTION MEETING.....	7
4	EARTHWORK CONSTRUCTION QUALITY ASSURANCE	8
4.1	Construction Monitoring and Testing.....	8
4.1.1	GENERAL	8
4.1.2	BULK EXCAVATIONS & FINISHING.....	8
4.1.3	SUB-soil drain & LEAKage detection - Gravel And sand INFILL LAYERS.....	9
4.1.4	Plant.....	11
4.2	CONSTRUCTION	12
4.2.1	Sub-soil and Leakage Detection Drains	12
4.3	TOLERANCES	12
4.4	Testing.....	12
4.4.1	Aggregates.....	12
4.4.2	Trench Backfill	12
4.4.3	Backfilling of Anchor Trench	14

4.5	Surveying	15
5	GEOSYNTHETICS CONSTRUCTION AND QUALITY ASSURANCE.....	17
5.1	Conformance Testing.....	19
5.2	Geosynthetics Construction Monitoring and Testing.....	20
5.2.1	ALL GEOSYNTHETIC INSTALLATIONS	20
5.2.2	Geomembrane	22
5.2.3	Geotextiles	53
5.2.4	Geosynthetic Clay Liner.....	57
5.2.5	Geocell with cement stabilised soil infill.....	74
5.2.6	Geogrid.....	77
6	DOCUMENTATION	79
6.1	Daily Record keeping.....	79
6.2	Observation Logs and Testing Data Sheets.....	79
6.3	Construction Problem and Resolution Documentation	80
6.4	Photographic Documentation.....	80
6.5	Design and Specification Changes.....	80
7	CQA FINAL REPORT	82
7.1	Submission of report	82
7.2	CQA Final Report Contents	82
7.3	Record Drawings	82
7.4	Geomembrane guarantee	83
	LIST OF APPENDICES	83
	ENGINEER.....	84
	CQA OFFICER.....	85
	MAIN CONTRACTOR.....	85

List of Tables

Table 1: Material Properties & Testing Regime for Bulk Excavations.....	9
Table 4: Material Properties & Testing Regime for Sub-soil Drainage and Leak Detection System	13
Table 5: Engineered fill and anchor trench backfill construction testing	14
Table 6: HDPE Resin Properties	24
Table 7: HDPE Sheeting Material Performance Requirements	24
Table 8: Air Channel Test Pressures for HDPE Geomembranes	43
Table 9: Allowable Pressure Loss In Air Channel Test	44
Table 10: Seam Specimen Test (ASTM D4437) Specifications.....	47
Table 12: Type A Geotextile Manufacturer QA/QC Requirements	55
Table 12: Type B Geotextile Manufacturer QA/QC Requirements.....	56
Table 13: GCL Manufacturer QA/QC Requirements	62
Table 14: GCL Installation Tolerances.....	71
Table 15: Employer/Owner Project Professional Team Members (key persons)	84
Table 17: CQA Personnel	85
Table 18: Employer/Owner Project Professional Team Members (key persons)	85

1 INTRODUCTION

1.1 QUALITY ASSURANCE (QA)

This Construction Quality Assurance (CQA) Plan has been prepared to describe the necessary quality control and quality assurance testing regime required to assure the Employer, Regulatory Authority, and all Interested & Affected Parties that the pollution control barrier system designed by the Engineer has been **procured, manufactured, and installed**, in such a way that its performance aligns with the design assumptions and requirements.

The intent of the CQA Plan is to dictate the necessary to demonstrate that the Contractors and Installers have met their obligations in the supply and installation of components and materials according to the Construction Drawings, Construction Specifications, and meets the appropriate regulatory requirements.

The objective of this plan is to establish:

- **Duties of parties** responsible for the CQA program,
- **Qualification requirements** of the CQA Engineer(s),
- **Inspection activities**,
- **Sampling & Testing** procedures during construction,
- **Document control** measures,
- **Procedures** for approving the materials used for construction,
- **Methods for assuring compliance** to design standards and specifications,
- **Procedures for resolving issues** that may occur concerning the design and construction, and
- **Documentation of construction and testing** for submittal to the regulatory authority for their review.

1.2 QUALITY CONTROL (QC)

Quality Control (*not to be confused with Quality Assurance*) is provided by the Manufacturers, Installers, and Contractors and refers only to their actions (and the records of these actions) taken to ensure that materials and workmanship meet the requirements of the Construction Drawings, Specifications and Regulatory Requirements.

2 PARTIES INVOLVED WITH CONSTRUCTION ASSURANCE

The following section provides descriptions of the parties referred to in this CQA Plan including their responsibilities and qualifications. (The **SANS 10409** standard specification as amended has particular reference).

2.1 EMPLOYER

As defined in Conditions of Contract in the Project Contract Document.

For this project: LAFARGE LICHTENBERG CEMENT PLANT - OWNER/OPERATOR

The Owner/Operator of the facility is defined as the person or juristic entity that holds the site license and is responsible by law to meet to the license conditions.

For this construction contract, the Owner and the Operator is the same entity as the Employer and use of the word Employer will be synonymous with Owner/Operator.

As such, in this case, the responsibilities of the Owner/Operator will apply to the Employer.

2.2 CONSTRUCTION MANAGER

The Construction Manager will be a representative of JG Afrika (Pty) Ltd or duly appointed representative, on behalf of the Owner.

The Construction Manager is responsible for overseeing the construction activities at the facility (Lafarge Lichtenberg PCD(s)). The Construction Manager is responsible for overseeing the construction of the lining system to be undertaken by the Main Contractor, ensure that the Contractor's quality control plan is being instituted and that all quality assurance activities for the project are being undertaken.

The Design Engineer/Construction Manager (for this project) is also responsible for the design and preparation of the Construction Drawings and Construction Specifications. The Design Engineer/Construction Manager is responsible for approving all design and Construction Specification changes, modifications, or clarifications encountered during construction.

NOTE: Refer to Appendix A for Detailed List

2.3 DESIGN ENGINEER

The Design Engineer is the firm JG Afrika (Pty) Ltd represented by Mrs. Jan Norris Pr Eng.

The Design Engineer is responsible for having designed the Works, as well as having issued the construction drawings that detail the requirements of the design.

The Design Engineer shall be responsible for engaging with the Construction Manager and resolving all technical and quality assurance issues that arise during the construction of the Works and must be involved in any decisions that may affect the design, specification or requirements of the basal lining system or future operations of the waste impoundment.

2.4 EMPLOYER'S AGENT

The Employer's Agent is a contractual term with reference to the **LIC II-1 General Conditions R01** and their roles and responsibilities are defined in terms of the contract.

For the purposes of this contract, the Employer's Agent may be the Design Engineer (a representative of JG Afrika) or the Employer will act as their own agent in terms of the Contract, with the option of JG Afrika acting as a 3rd party mediator if required/requested by the contracted parties.

2.5 CONSTRUCTION QUALITY ASSURANCE OFFICER (CQAO)

The CQA Officer is a party, independent from the Employer, Manufacturer, Geosynthetic Membrane Installer and Contractor, that is responsible for observing and documenting activities, and providing advice related to the CQA of the production, installation, testing, repair, and covering of the geosynthetic lining system.

The CQA Officer, will be responsible for understanding this CQA Plan and shall ensure that CQA testing, monitoring, documentation, and reporting as required by this CQA Plan are undertaken by the parties to the construction. The CQA Officer will stamp the final construction report. The implementation and reporting of this CQA Plan shall be conducted under the direct supervision of an ECSA registered professional engineer/technologist with appropriate experience and expertise in solid waste management and/or pollution control dam design and construction. The CQAO will also be responsible for assessing and approving the Main and Civil Contractors QCP, as well as the Geosynthetic Installers QCP prior to works commencing. The CQAO will also be only the entity to be able to authorise a change in the QCP or requirements of the CQA Plan after consultation with the Design Engineer.

The CQAO will report to the Design Engineer (copying in the Owner/Operator) and may be an employee of the Design Engineer.

2.6 MAIN CONTRACTOR

The Main Contractor is as defined in **LIC II-1 General Conditions R01** and will be determined based on the outcome of a quotation process administered by Lafarge Lichtenberg Cement Plant.

The Main Contractor is responsible for completion of the construction work as defined by construction contract with the Employer and in accordance with the Project Drawings and Project Specifications including materials provided by the Geosynthetics Manufacturer and work performed by the Geosynthetics Installer.

The Main Contractor maintains all construction insurances and liability for the works. The main contractor shall be responsible for retaining a surveyor to set lines and grades required for excavation, construction, and preparation of as-built drawings. Surveying shall be performed under the direction of a registered Surveyor.

2.7 CIVIL CONTRACTOR

The Civil Contractor shall mean a Civil Engineering Contracting firm responsible for the construction of earthworks, engineered earth layers and normal civil engineering (pipelines, manholes etc.) construction aspects of the Works. The Civil Contractor can either be the Main Contractor or can be subcontracted by the Geosynthetic Membrane Installer, who would then be the Main Contractor. The Civil Contractor will be responsible for ensuring the quality of the construction works through their preparation of their own Construction Quality Control

Plan (QCP), taking into the specifications and requirements of the design, specifications, CQA document requirements, identified SANS and GRI codes, and SANS 1200 series for the type of works being conducted. The Civil Contractor will be required to prove they have met the requirements of their own QCP at the end of construction.

2.8 GEOSYNTHETIC MEMBRANE (GSM) MANUFACTURER

The GSM Manufacturer, or Manufacturer, is responsible for the production of the GSM and some prefabricated appurtenant components as necessary. The Manufacturer **MAY NOT** be the Geosynthetics Installer. Each Manufacturer must pre-qualify that they are able to produce material that meets the requirements of the Construction Specifications.

2.9 TRANSPORTER

The Transporter is responsible for the transportation of the geosynthetic products (rolls) from the Manufacturer to the Site. The Transporter may be an employee of the Contractor or Geosynthetic Manufacturer, but should have the necessary training, expertise and knowledge to deliver the material to site without comprising the integrity or quality of the product provided.

2.10 GEOSYNTHETIC MEMBRANE (GSM) INSTALLER

The GSM installer shall mean the contracting firm responsible for the installation of the geomembrane lining system in accordance with the Construction Drawings and Construction Specifications. The GSM installer can either be the main contractor or can be sub-contracted by the Main Contractor (when acting as the Civil Contractor). The Installer must pre-qualify by meeting the requirements outlined in the Construction Specifications and/or Tender Eligibility Requirements. The Geomembrane Installer **MAY NOT** be the Geomembrane Manufacturer.

The GSM will be responsible for ensuring the quality of the construction works through their preparation of their own Construction Quality Control Plan (QCP), taking into the specifications and requirements of the design, specifications, CQA document requirements and requirements identified SANS and GRI codes, for the type of works being conducted. The GSM will be required to prove they have met the requirements of their own QCP at the end of construction.

2.11 INSTALLATION SUPERVISOR (SUPERINTENDENT)

The Installation Supervisor shall be a suitably qualified and experienced person responsible for all aspects of the specified installation of the geosynthetic membranes. The Installation Supervisor shall be an employee of the GSM installer who will provide full-time technical guidance to the field crew.

The Installation Supervisor will present at all progress meetings. Welding technicians shall be certified as competent by the International Association of Geosynthetic Installers, or equal approved independent oversight body. The CQAO, through the Construction Manager, reserves the right to reject any welding technician whose performance is unsatisfactory.

2.12 INDEPENDENT CONSTRUCTION QUALITY ASSURANCE (CQA) LABORATORY

The Independent CQA Laboratory is a third-party laboratory, independent from the Employer, Construction Manager, Design Engineer, Operator, Manufacturer, Installer, and Contractor, that is responsible for conducting independent tests on samples of geosynthetic products.

The CQA Lab is directed by the Construction Manager and CQAO. The geosynthetics testing laboratory shall be accredited by the Geosynthetics Research Institute Laboratory Accreditation Program (GRI-LAP or similar) as far as reasonably possible, or as otherwise agreed with the CQAO.

3 MEETINGS

3.1 PRE-CONSTRUCTION MEETINGS

Following the award of the Contract and prior to the ordering of material and thus commencement of construction work, a Pre-Construction Meeting will be held. This meeting will include all parties involved, including the CQAO, the Construction Manager, the Design Engineer, the Main Contractor, the Employer and the Installer (inclusive of installation supervisor).

The purpose of this meeting is to begin planning for co-ordination of tasks, to anticipate any problems which might cause difficulties and delays in construction, and, above all, to present the CQA Plan to all of the parties involved. It is very important that the procedures regarding testing, repair, etc., be known and accepted by all.

The first part of the Pre-Construction Meeting may be devoted to a review of the design drawings and specifications. Any necessary amendments would be carried to a Resolution Meeting to be resolved.

This meeting should include all of the following activities:

- Review critical design details of the project,
- Review the Project Specifications,
- Review the CQA Plan (where separate from Project Specifications),
- Review the Manufacturer's and Installer's QC Programs for compatibility with other project documents,
- Review the panel layout drawing supplied by the Installer,
- Make appropriate modifications to the CQA Plan to ensure that it identifies all necessary CQAO,
- Define lines of communication, responsibility, and authority
- Decide the number of geomembranes seaming units to be maintained on-site by the Installer (this number depends on the number of seaming crews and on the type of seaming equipment),
- Review and Establish work area security and health and safety protocols,
- Confirm the methods for documenting and reporting data, and for distributing documents and reports.

The meeting will be chaired by the Employers Agent and will be documented by a person designated at the beginning of the meeting, or by the CQAO. Minutes will be distributed to all parties.

3.2 PROGRESS MEETINGS

Progress meetings will be held (frequency to be confirmed during pre-construction meeting). At a minimum, these meetings will be attended by the CQAO, the Construction Manager, the Installer, the Installation Supervisor and the Main Contractor. The CQAO (or Construction Manager's Representative) is responsible for organizing and conducting the progress meetings. The purpose of this meeting will be to:

- Review the previous weeks accomplishments and activities,

- Review upcoming scheduled work and project milestones,
- Discuss any problems or potential construction problems,
- Review the results and status of CQA field and laboratory testing,

This meeting will be documented by the CQAO (or Construction Manager's Representative) and the minutes transmitted to all in attendance.

3.3 RESOLUTION MEETING

The special meeting will be held when, and if, a problem or deficiency has occurred, or is likely to occur that requires special action decisions by several parties. The meeting will be attended by the Construction Manager, the CQAO, and other involved parties. If the problem requires a design modification, the Design Engineer (if separate from Construction Manager) should also be present.

The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- Define the problem or deficiency,
- Establish the cause,
- Define possible solutions,
- Select a suitable technical solution agreeable to all parties, and
- Define an action plan to implement the solution.

If unsatisfactory test results identify a deficiency, additional tests will be performed to define the extent of the deficient material or work area. The Installer or Main Contractor shall correct the deficiency to the satisfaction of the Design Engineer and CQAO. Design revisions can only be made by the Construction Manager with approval by the employer in accordance with delegated authority by employer to Employers' Agent (LIC II-1 General Conditions R01, as applicable).

The corrected deficiency shall be re-tested and/or approved before any additional related work is performed by the Installer or Main Contractor. Re-test results shall also be recorded by the CQAO and included in the final report documentation.

4 EARTHWORK CONSTRUCTION QUALITY ASSURANCE

Construction of the earthworks components of the lining system must be in accordance with the approved Project Drawings and Project Specifications. This section of the CQA Plan establishes the CQA monitoring, and testing program designed to ensure compliance with the Project Drawings and Project Specifications for earth materials.

Quality assurance testing and observation is required during excavation of sub-grade, procurement of imported materials, crushing and processing of any construction waste and/or use of in-situ materials for use in the works (where applicable), placement of the specified engineered fill, and construction of the earth of the liner system components for the lining system.

4.1 CONSTRUCTION MONITORING AND TESTING

4.1.1 GENERAL

All components of the construction shall be observed and tested as required by the CQA Plan and as ordered by the CQAO to verify that the construction is in accordance with the Project Specifications. The CQAO Auditor shall review the work performed by the CQAO and Construction Manager and confirm that the findings made, are being addressed with the Geomembrane Installer and reported on at progress meetings.

The survey required for specific layers throughout the construction process shall be made to evaluate whether the materials are placed to the levels, thicknesses and grades as shown on the Project Construction Drawings, to the tolerances specified in the CQA Document, Contract Document and SANS 1200 D, as amended.

The Contractor will provide the necessary CQA documentation to the CQAO and Construction Manager timeously, so as to be reviewed against the CQAO's own records, so that it may be reviewed and accepted. Specific CQA observation and/or testing are required for the following earth layers during construction:

- Bulk Excavations and Finishing,
- Bulk Formation Layer,
- Sub-soil Drainage & Leak Detection Gravel and sand Infill,
- Selected Cohesive Cushioning Layer, and
- Anchor Trench Excavation and Backfill.

Note: All shear box tests specified as per ISO17892-10:2018 are to be conducted using confining pressures of 50, 100 and 200 kPa respectively, in line with expected loading conditions.

4.1.2 BULK EXCAVATIONS & FINISHING

The bulk excavations shall be conducted on the in-situ material on site. Bulk cut will be excavated and stockpiled and may require further processing before being considered acceptable for use in the preparation layer. Lafarge will have to confirm ownership and availability of the in-situ material prior to excavation by the Contractor for use in engineered layers, subject to the material meeting the specification after the Contractor has processed it accordingly. The Contractor may also sample other material from designated areas on other

stockpiles of material available on site, providing this does not interfere with Operations and approval has been granted by Lafarge.

The top 150mm of material shall be ripped and re-compacted to min. 93% Standard Procter density at OMC +2% prior to placement of the GCL. Where the basal excavation is on hard rock a 100mm thick cushioning layer, comprising of selected cohesive material shall be placed and compacted to min. 93% Standard Procter density at OMC +2% prior to placement of the GCL. The Contractor will consider, source, and use appropriate plant (such as sheep's foot roller) to successfully compact the material to meet this specification noting the embankments are at 1V:3H, and a smooth drummer roller or similar will struggle to operate when material is wetted to OMC.

The selected and/or processed material (from excavations and/or stockpile) must be free of roots, rocks, debris, organic and any other deleterious materials. For this purpose, and to comply with below specifications, the Contractor is to assume screening and processing of the material will be required to the requirements in Table 1, and to be priced accordingly.

The Design Engineer and CQA Officer reserve the right to increase the frequency of testing should the results offered not meet the specification in Table 1 below. This is minimum assurance testing required from the CQA, however the Contractor is required to complete their own construction quality control as a minimum to SANS 1200 D requirements to ensure the quality of the works.

Table 1: Material Properties & Testing Regime for Bulk Excavations

COMPACTION (based on Procter Density)				
Nuclear Density Gauge	Min. 95% MDD	ASTM D6938	1 per 1 000m ²	As per SANS 1200D
Sand Replacement Test	Min. 95% MDD	ASTM D1556	1 for every 10 NDG Tests	As per SANS 1200D
GRADING				
Free of Roots, Debris, etc	--	Visual Inspection by CQAO	Prior to next layer being installed	As per SANS 1200D

4.1.3 SUB-SOIL DRAIN & LEAKAGE DETECTION - GRAVEL AND SAND INFILL LAYERS

Stone aggregate used in the sub-soil drainage collection and leakage detection system (which is the one and the same, as the same drain performs both functions) will be a minimum 300mm thick layer of natural pea gravel or crushed stone material, screened to 6.7 mm obtained from commercial sources and placed around the slotted collection pipe. A sand layer whose particle distribution envelope will be developed once the GCL cushioning layer has been selected will be determined after the cushioning material has been sourced and tested. This is to ensure the sand layer provides an adequate natural filter layer the layer above whilst ensuring piping does not occur. The sand layer to be placed in a minimum of 150mm thick layer.

The material to be used in the construction of the sub-soil drainage layers shall be of clean, selected, crushed stone and sand obtained from, on site, off site or commercial sources and be free of vegetation or waste. The material shall comply with the following properties:

4.1.3.1 APPROVAL OF MATERIALS

The Contractor shall supply in good time to the Engineer for his approval, samples of the materials that he proposes to use in the Works. Samples shall be accompanied by results of tests performed by an approved laboratory on the materials or certificates to the effect that the materials conform to the specified standards.

4.1.3.2 AGGREGATES

The Contractor is to take sufficient samples of the filter materials as placed in the drains to confirm that the material has not been contaminated during the stockpiling and placing procedure. A minimum rate of testing is 1 sample per 100 m³ placed. This rate is subject to change at the discretion of the engineer based on material consistency.

Layer thicknesses of the filter drains to be confirmed by excavation of test holes into each layer at a nominal spacing of 25 lineal metres, these holes are to be witnessed by the Engineer.

The Contractor is to submit all test results (gradings and thicknesses) for the section of drain under construction for each individual layer, this is to be approved and signed off by the Engineer prior to placing the next layer.

4.1.3.2.1 6.7 MM STONE

Pea gravel shall be a hard, clean and durable crushed stone and shall comply with the grading envelope shown below.

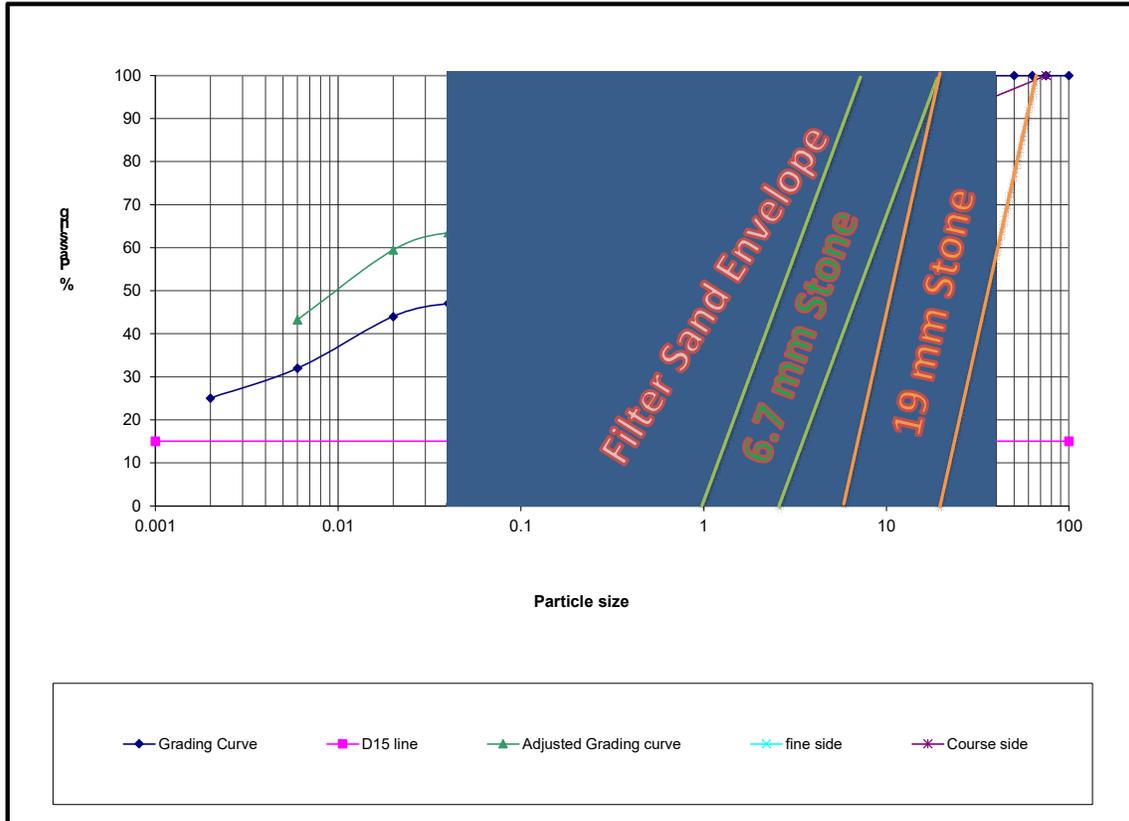
Sieve Size [mm]	Material Passing [%]
9.5	70 - 100
6.7	45 - 95
4.75	30 - 75
2.36	0 - 40
1.18	0 - 10

4.1.3.2.2 FILTER SAND

Filter sand shall consist of clean hard particles and shall comply with the grading envelope shown below.

Sieve Size [mm]	Material Passing [%]
19.0	85 - 100
9.5	70 - 100
6.7	70 - 100
4.75	60 - 100

1.18	25 - 95
0.6	10 - 55
0.3	0 - 25
0.15	0 - 10



4.1.3.3 DRAINAGE PIPES

Sub-soil pipes shall be 160 mm dia. HDPE Drainex drainage pipes installed with the solid portion of the pipe downwards, including all couplings and fittings.

Main collector pipes shall be 160 mm dia. HDPE Drainex drainage pipes installed with the solid portion of the pipe downwards, including all couplings and fittings.

***Note** : Suitable alternative drainage pipes shall be considered but require approval of the engineer.

4.1.3.4 GEOTEXTILE

The geotextile shall be an approved non-woven filter fabric with the same performance and durability specifications as the grade specified on the drawings and referenced above.

4.1.4 PLANT

The Contractor shall provide such plant as may be necessary for trenching and backfilling, placing of filter materials and laying of pipes.

4.2 CONSTRUCTION

4.2.1 SUB-SOIL AND LEAKAGE DETECTION DRAINS

4.2.1.1 EXCAVATION

Sub-soil drains shall be excavated in the compacted basal fill or in situ material to the dimensions, lines and levels shown on the drawings. Excavated material shall be placed clear of the trench and will be used to form a berm alongside the toe of the stockpile (if required). The bottom and sides of the trench shall be neatly trimmed and loose material on the trench bottom removed and compacted at the optimum moisture content.

4.2.1.2 PLACING OF MATERIALS

The materials shall be laid as shown on the drawings to the specified thickness within the tolerances specified in Clause 6. The top surface of each layer shall be raked smooth before placing the next layer. During spreading of upper layers, care must be taken not to disturb the underlying layer.

Geotextile shall be laid with laps of at least 200 mm. Laps shall be stitched or heat bonded.

Pipes shall be laid carefully to specified line and level on the stone or gravel bed as shown on the drawings. Perforated pipes shall be laid with closed joints using collars or bell and spigot type coupling. After pipe laying has been approved, the stone or gravel surround shall be completed, the material being lightly tamped around and over the pipe, care being taken not to disturb the pipe.

4.3 TOLERANCES

The permissible deviation from specified thickness for filter and drainage materials shall be -0 to + 25 mm. In addition, the average of a series of thickness measurements on the filter sand shall not be less than the specified value.

4.4 TESTING

4.4.1 AGGREGATES

Samples shall be taken from at least every tenth load of 6.7 mm stone delivered to the site and a grading analysis done to ensure conformity with the specified grading.

Layer thicknesses of the drains to be confirmed by excavation of test holes into each layer at a nominal spacing of 25 lineal metres, these holes to be witnessed by the Engineer.

4.4.2 TRENCH BACKFILL

Field density tests shall be done at regular intervals on the common backfill placed in trenches. The density shall not be less than that specified for the adjacent material.

Table 2: Material Properties & Testing Regime for Sub-soil Drainage and Leak Detection System

<u>Material Property</u>	<u>Required Range</u>	<u>Test Method</u>	<u>Test Frequency</u>
GRADING (Sub-soil and Leak Detection Drains – Primary stone layer)			
Max Particle Size (mm)	See above tables	COLTO TMH 1 – Method A1	1 per 1 000 m ²
Min Particle Size (mm) – For Basal Lining	See above tables	COLTO TMH 1 – Method A1	1 per 1 000 m ²
Visual-Method Soil Classification	--	ASTM D2488	Continual during excavation and placement of soils
CRUSHING VALUE			
Aggregate Crushing Value	<29	COLTO TMH 1 – Method B1	1 per 1 000 m ²
Wet 10% FACT, and a wet/dry Venter test of Class I, II or III.	≥60kN	COLTO TMH 1 – Method B3	1 per 1 000 m ²
GENERAL PROPERTIES			
Free of Roots, Debris, etc	--	Visual Inspection by CQAO	Prior to next layer being deployed

NOTE: The Design Engineer/Construction Manager reserves the right to alter the material property requirements to suit material available by altering the design, should it be evident that failure to amend the design to suit available material and being an unforeseeable circumstance will result in economic impact on the Employer.

Should this event occur, changes to the design will be noted in the CQAO Report, detailing the reasons and justification for the change in specification.

Construction observation and monitoring required during the placement of the leak detection Layer and primary leachate collection layer includes:

- Verification that all pre-construction testing has been performed and that laboratory test results indicate compliance with the Construction Specifications. The CQAO shall assure that the Construction Manager and the Contractor receive prompt notification of material conformance,
- Verification that the material upon which the gravel will be placed has been installed in accordance with the Construction Drawings and Specifications, and that all required testing, and as-built documentation have been completed,
- Observe that care is taken when placing the drainage gravel on the Separation Geotextile and that the geotextile is not punctured or damaged during placement of the aggregates,
- Observe and document the placement of the sub-soil drainage pipes, aggregates and sand during backfilling, and ensure appropriate light ground pressure equipment is used for handling the gravel material, preferably tracked - equipment. No heavy machinery is to be used when handling material in close proximity to any liner system (GCL or geomembrane) that may have already been deployed,
- No mechanical plant is to operate directly over geosynthetic layers.
- Collect and transmit to the laboratory the required number of samples for testing of Sub-soil Drains.
- Communicate with the laboratory to verify that the materials tested comply with the Construction Specifications,
- Visually observe the gravel and sand materials to inspect for any variability in the material including variation in gradation, any fines or any deleterious material present,

- Verify that the CQA Survey has been completed and that the Record Drawings furnished by the surveyor indicates compliance with the lines, grades, elevations, and tolerances as indicated by the Construction Drawings and Specifications.

4.4.3 BACKFILLING OF ANCHOR TRENCH

Anchor trenches will be adequately drained to prevent ponding or softening of the soils while the trench is open. Anchor trenches will be backfilled and compacted by the Civil Contractor subject to requirements of Table 3, with selected soil from site. Where it is not possible to use material from site due to high fines content, sand or granular material will be imported. Anchor trenches should be backfilled in layers not exceeding 200mm loose.

Care must be taken when backfilling the trenches to prevent any damage to the geosynthetics. Sharp rocks and stones shall be removed from soils before filling in the anchor trench. There shall be no holes in the geomembrane placed in the anchor trench. The CQAO (or CQAO Auditor) will observe the backfilling operation and advise the Construction Manager of any problems.

The backfilling of the trenches shall be done in accordance with SANS1200DB, with particular reference to SANS1200 DB, Clause 5.7.1.

CQA observation and/or testing is required during construction to verify that the materials and construction are in accordance with the Construction Specifications. The tests to be performed, including testing frequency, are shown below. The testing frequencies specified in the table below may be increased when construction conditions warrant additional tests.

Additional tests may be recommended by the CQAO (or CQAO Auditor) and approved by the Construction Manager.

Table 3: Engineered fill and anchor trench backfill construction testing

Test Designation	Requirements†	ASTM Designation	Frequency
GRADING			
Max Particle Size	19mm	COLTO TMH 1 – Method A1	1 per 150 m ³
Percentage Passing 2mm Sieve	<30%		1 per 150 m ³
Percentage Passing 0.075mm Sieve	<15%		1 per 150 m ³
Visual-Method Soil Classification		D2488	Continual during excavation and placement of soils
COMPACTION			
Nuclear Moisture/Density ¹	90% Mod. AASHTO	ASTM D6938	1 per 400 m ³
Sand Replacement Test	90% Mod. AASHTO	ASTM D1556	1 per 400 m ³

NOTE:

- Tests shall be performed for every 150 m³ of material placed within anchor trenches. For large fills in small areas, the testing frequency shall be increased as necessary to ensure testing for each lift of soil placed
- Anchor trenches will be excavated by the Civil Contractor (unless otherwise specified) to the lines and dimensions shown on the design drawings, prior to geomembrane placement.
- The edge of the trench, over which the geomembrane enters the trench, will be rounded to avoid sharp bends in the geomembrane. There shall be no sharp protrusions on the inside wall of the trench. No loose soil will be allowed to underlie the geomembrane in the trenches.
- Water shall not be allowed to stand, or soften the soil, in the anchor trench. Responsibility for dewatering of the anchor trench shall reside with the Main Contractor.
- The anchor trench shall be inspected as well as approved by the Construction Manager and CQAO (or CQAO Auditor) before geomembrane placement, backfilling and compaction of the anchor key material.
- A mix design for the cement stabilisation of the anchor trench will be submitted to the Construction Manager and CQAO for approval prior to proceeding with the anchor trench backfill so moisture requirements can be monitored.
- Under no circumstances must the protective cement stabilised sand layer be placed on embankments unless anchor trenches have been closed and approved by the Construction Manager and CQAO.

4.5 SURVEYING

4 separate layouts records will be surveyed, and a detailed record kept of the panel placement for the following:

- 1) Geosynthetic Clay Liner (GCL) Panel Layout
- 2) HDPE Liner Panel Layout,
- 3) Protection Geotextile Panel Layout, and
- 4) Wrinkle Formation Layout.

The record drawings above will include at least the above (as applicable):

- The locations of all geosynthetic membrane joints and the types of joints. Especially transverse joints on slopes where the slope length exceeds the GCL roll length,
- GSM/GCL panel and roll numbers, and GSM/GCL type,
- The location of all geosynthetic membrane repairs and the types of repairs,
- Toes and Crests of slopes,
- Location of anchor trenches,
- Location and numbers of any GSM destructive test sample sites,

- Construction details and tolerances that differ from as-designed details.

In addition to the above, it will be a requirement to submit an initial panel layout for each of the liner elements for review by the Design Engineer and CQAO prior to commencing with the Works. The Contractor's attention is also drawn to the requirements of SANS 10409:2020 and must comply with the requirements contained within over and above the requirements above.

5 GEOSYNTHETICS CONSTRUCTION AND QUALITY ASSURANCE

Construction of the specified geosynthetics must be in accordance with the approved Project Drawings and Project Specifications. This Quality Assurance program consists of reviewing Geosynthetics Manufacturer's and Installer's Quality Control submittals, material conformance testing, and construction monitoring and testing.

The types of geosynthetics used in the barrier system construction include geotextile, geocell, geomembrane, geosynthetic clay liner and HDPE pipe and fittings. These geosynthetics are defined in the Project Specifications. Prior to and during construction, these geosynthetics shall be sampled and tested to determine if they conform to the Project Specifications. All geosynthetic conformance testing shall be the responsibility of the Geosynthetic Installer and CQAO. Review Quality Control PROCESSES

Quality Control from the Geosynthetic Manufacturer is critical to the success of the barrier system installation. The QA process extends beyond construction in this regard and must be applied as early as possible. For this reason, QA is an inherent part of the review of the appointed geosynthetic supplier and installer, in order to ensure that a Geosynthetic Manufacturer and Installer that are selected for the project have the necessary expertise to execute the work to the required standard.

AT APPOINTMENT STAGE

The Design Engineer will review the potential installers put forward as part of the quotation process, and approve that the proposed Geosynthetics Supplier and Installer have sufficient experience in the opinion of the Design Engineer to complete the supply and installation of the materials. This "pre-screening" eliminates unqualified manufacturers or installers from being awarded the work. In particular for the Class C Barrier System specified in this Contract, an experienced installer and manufacturer is essential due to the associated risks of non-containment of the leachate.

The Design Engineer will review at least the following, and then make a recommendation to the Employer as to whether the Geosynthetic Supplier and Installer are suitable:

1) Geosynthetic Membrane (supply / manufacture, installation and surveying).

Geosynthetic Membrane (GSM) Manufacture

- Details of the Manufacturer(s) (i.e. name, company registration, location etc.)
- Information on plant size, equipment, number of shifts per day, and capacity per shift,
- List of material properties, including certified test results (to be supplied if requested by the Employer).
- Completed Projects; provide details of completed projects for material manufactured where the geomembrane materials are equal to that described below:
 - **For HDPE smooth-textured geomembrane:** Completed projects totalling a minimum area of 100,000 m² for which the Manufacturer has manufactured geomembrane materials equal to that proposed to be used for this Contract.

- It is required that the Manufacturers of the geosynthetic membranes have ISO 9002: 1994 or ISO 9001:2000 certification or more recent if applicable,

2) Geosynthetic Membrane (GSM) Installation:

The Installer must be trained and qualified to install the GSM's specified in this Contract. If the Contractor is not an installer with the necessary experience and qualification, then a suitably qualified firm of installers must be sub-contracted.

The following information regarding the GSM Installer(s), as a minimum, must be completed/submitted with the Tender

- Corporate background and information and declare ISO 9002: 1994 or ISO 9001:2000 certification,
- Information on equipment, personnel and anticipated daily production (to be completed).
- Written confirmation that all design features, Specifications, and requirements of the CQA Plan can be complied with.
- Completed Projects: Provide details of completed projects for which the Installer has installed similar geomembranes with a minimum total area of 100,000 m² being installed.
- The Installation Supervisor must be qualified by experience. The Installation Supervisor must have supervised the installation of a minimum of 100,000 m² of geosynthetic membrane.
- It is required that the installers of the geosynthetic membranes have ISO 9002: 1994 or ISO 9001:2000 certification or more recent if applicable

3) Geosynthetic Clay Liner (Manufacture):

In order to be considered responsive in terms of this tender, the tendering entity or the tenderer's proposed sub-contractor, must supply at minimum the following information:

- Corporate background and information and declare ISO 9002: 1994 or ISO 9001:2000 certification or more recent if applicable
- Information on plant size, equipment, number of shifts per day, and production per shift,
- List of materials used, material properties, including certified test results and further details of completed projects (to be supplied if requested by the Employer).
- Completed Projects; provide details of completed projects for which the Manufacturer has produced the same geosynthetic clay liners with a minimum total area of 1,000,000 m² being manufactured.

AT CONSTRUCTION STAGE

Prior to geosynthetic installation, the Construction Manager and CQAO will review the Geosynthetic Installer's Quality Control Program to confirm that testing regime and QC process aligns with the National Standards and Specification. The CQAO or Construction Manager will review the following for each geosynthetic material specified for the Project:

- Geosynthetic material samples, and minimum material specifications which shall include the Manufacturer's minimum physical properties of the material, test methods (ASTM Standards) used, and factory seaming methods
- The origin (supplier's name and production plant), identification (brand name and number) and material properties of the resin used to manufacture the product,
- Geosynthetics Installer's Quality Control Manual, for the installation and testing of the geosynthetic,
- A copy of each of the Quality Control Certificates on each lot of resin issued by the resin Supplier for the specific material for this project. Geomembrane submittals shall include certification of the resin for extrusion welding rod,
- The result of quality control testing conducted on the resin used in manufacturing the specific material for this project,
- A list which correlates the resin to the individual geosynthetic rolls and extruded materials
- A copy of the geosynthetic roll Quality Control Certificates which shall be supplied at a minimum frequency of one 1 per every 5, 000 square meters of geosynthetic material continuously produced and supplied to the project unless otherwise presented in the Construction Specifications,
- A panel layout drawing for geomembrane showing the proposed installation layout identifying field seams as well as any variance or additional details which deviate from the Construction Drawings
- A detailed installation schedule for the project,
- Certification that the extrusion welding rod to be used is comprised of the same resin type as the geomembrane to be used (geomembrane only)

5.1 CONFORMANCE TESTING

Conformance Testing will be performed and approved prior to shipment and also on arrival of material on site. Durability tests are to be conducted as soon as the material is manufactured.

Conformance Testing may, at the discretion of the CQAO, be carried out by an independent laboratory (QCA laboratory). Conformance testing is not an opportunity to reproduce the QC testing program. It is a check to provide confirmation that satisfactory material is delivered to the site. The name and address of the laboratory shall be approved by the Construction Manager. The Construction Manager has the right to reject any roll or production batch if the samples do not pass the conformance testing.

The Construction Manager shall mark the machine direction and roll number on the sample, and date the sample was obtained and forward the sample to the geosynthetic laboratory. All conformance tests shall be performed in accordance with the Construction Specifications.

The CQAO (or Construction Manager) along with the CQAO Auditor shall review the test results and shall report any non-conformance to the Construction Manager and the Installer.

5.2 GEOSYNTHETICS CONSTRUCTION MONITORING AND TESTING

The GSM manufacturer shall issue Quality Control submissions to the Construction Manager and CQA officer for each delivery of material. The submissions shall include the following information:

Prior to the shipment of any geomembrane, the Manufacturer will provide the CQAO (or Construction Manager) with the following:

- A certified properties sheet including, at a minimum, all specified properties (parameters), and test methods indicated in the specifications,
- A list of quantities and descriptions of materials other than the base polymer which comprise the geomembrane, and
- The internal MQC sampling procedures, frequencies of testing, and results of testing of material supplied to the project.

The CQAO (or CQAO Auditor) will verify that:

- The property values certified by the Manufacturer meet all of the Project specifications; and
- The measurements of properties by the Manufacturer are properly documented, the test methods used are acceptable, and the geomembrane meets the Project Specifications.
- GSM Manufacturer Tracking List - Cross-referencing list delineating the corresponding lots for the materials used in the production of the rolls delivered.
- Manufacturing Quality Control Data - The manufacturing quality control test data indicating the actual test values.
- Physical Properties Sheet - The material specification for the geomembrane supplied in accordance with this specification.
- Letter of Certification - The letter indicating that the material is in conformance with the physical properties specified

5.2.1 ALL GEOSYNTHETIC INSTALLATIONS

The CQAO (or Construction Manager) along with the CQAO Auditor, will ensure that the Main Contractor is, at **MINIMUM**, undertaking the following checks for all geosynthetic installations. More emphasis or detail may be added to these checks in subsequent sections:

- Delivery and unloading of geosynthetic materials to the site to verify that the materials are not damaged and are properly labelled,
- Obtaining geosynthetic packaging identification slips for verification and generation of an on-site materials inventory
- Subgrade conditions prior to liner installation and verify that any deficiencies (e.g. surface irregularities, protrusions, excessively soft areas, stones, desiccation cracks) noted are corrected,
- Verification that the Employers Agent has reviewed completed surveys,
- Handling of geosynthetic materials from storage to the work area,

- Temporary and permanent anchoring of geosynthetics to verify that Project Specifications are met,
- Verification that required overlap distances are met,
- A record of all incidents such as storms and fires which may have an influence on materials properties.

5.2.1.1 TRIAL PADS

Trial Pads are a useful tool in order to practice and refine installation conditions for site specific materials and conditions. For the purposes of this project, one trial pads is required for the GCL. Once the full trial pad is constructed, it will also be used to assess the potential for desiccation in the GCL to assist in identifying the required period in which the confining layer must be installed to prevent moisture loss, desiccation as well as unconfined swell and shrinkage in the GCL.

The Trial Pad may be extended to assess GCL - leachate compatibility if required.

Should the Employer, Design Engineer and CQAO feel that the conditions are significantly difficult to manage on site and therefore justify the need for additional trial pads to be constructed, an annexure to the CQA Plan will be provided at Construction Stage detailing the requirements for the installation of the Trial Pad.

NOTE: From this point onwards in the CQA Plan, there is a page break between each geosynthetic product specified purely for clarity and readability.

5.2.2 GEOMEMBRANE

5.2.2.1 MANUFACTURER REQUIREMENTS

5.2.2.1.1 SCOPE

The CQAO may perform an audit of the manufacturing and quality control procedures used by the Manufacturer, specifically for the production of the geomembranes to be used for installation at the Employer's facility. The Manufacturer shall give the Construction Manager and CQAO at least one month's notice of the start of production of geomembrane for this project. Quality Control tests shall be performed as the geosynthetic membrane is manufactured.

5.2.2.1.2 QUALITY CONTROL

The Manufacturer shall make available to the Employer, Contractor, Construction Manager, and CQAO, a Manufacturing Quality Control manual, which outline all quality procedures, to be implemented for the manufacture of the geosynthetic membranes.

The Manufacturer shall provide valid calibration certificates for laboratory testing equipment. The Construction Manager and CQAO shall verify that, during select runs of material, all MQC procedures are performed.

5.2.2.1.3 MANUFACTURING PROCESS

In general, the Manufacturer shall provide access for the Construction Manager/CQAO to all equipment used to manufacture the geosynthetic membrane. This does not include divulging trade secrets, formulations, and procedures, which are not commonly known as basic manufacturing processes, used for geosynthetic membranes. However, if the process is critical to the integrity of the manufactured geosynthetic membrane, the equipment shall be made accessible to the Construction Manager/CQAO.

The Construction Manager/CQAO shall monitor production and testing of GSM material allocated for this project. If material for this project has already been manufactured, the Construction Manager/CQAO shall monitor production of the same type of GSM on the same production line to verify that manufacturing controls are in place. Additional tests by one independent laboratory are also required before the material will be approved. The Construction Manager/CQAO shall review the QC certificates and notify the Manufacturer in writing which geomembrane rolls are approved for shipping. The Construction Manager/CQAO shall be allowed to monitor the loading of the geomembrane for shipping.

Where material, which has already been manufactured and has been delivered to storage in South Africa, the Construction Manager/CQAO shall be furnished with the test results from an independent laboratory and the QC certificates and will notify the Manufacturer in writing which geomembrane rolls are approved for shipping from storage. The Construction Manager/CQAO shall be allowed to monitor the loading of the geomembrane for shipping from storage.

The Main Contractor shall obtain written approval from the Construction Manager/CQAO before the GSM material is loaded for shipping.

5.2.2.1.4 MANUFACTURING OF GEOMEMBRANE

The following types of geomembranes are to be manufactured and installed, namely:

- Minimum 1.5mm thick smooth-smooth High-Density Polyethylene ("HDPE"), and
- Minimum 1.5mm thick smooth-textured High Density Polyethylene ("HDPE").

5.2.2.1.5 RAW MATERIALS

Only one type of resin (one manufacturer, one resin classification per HDPE) shall be used to manufacture geomembrane for this project.

Resin used in manufacturing geomembrane sheets shall be made of virgin uncontaminated ingredients. No more than 5 percent regrind, reworked, or trim material in the form of chips or edge strips shall be used to manufacture the geomembrane sheets. All regrind, reworked, or trim materials shall be from the same manufacturer and exactly the same formulation as the geomembrane sheet being produced. No post-consumer materials shall be used to produce the geomembrane. For geomembranes with plasticizers, only primary plasticizers that are resistant to migration shall be used.

The Contractor/Installer shall submit a copy of the Resin Manufacturers test reports and QC/QA certificates for the raw materials used in the manufacturing of the geomembrane shipped to the site.

The resin used must adhere to the GRI-GM13 for HDPE, latest edition based on date of tender.

Internal Quality Assurance testing will be carried out by the geomembrane Manufacturer to demonstrate that the incoming resin meets this specification. At the Client's discretion, additional conformance testing, paid for by the Owner, may be carried out at the CQA Laboratory. If the results of the Manufacturer's Quality Control (QC) Laboratory and the CQA Laboratory testing differ, the testing will be repeated by the CQA Laboratory, and the Manufacturer will be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

Prior to the installation of any geomembrane material, the Manufacturer will provide the Construction Manager and CQAO with the following information:

- The origin (resin Supplier's name), identification (type, lot number), and production date of the resin,
- A copy of the Quality Control certificates issued by the Resin Supplier.
- Reports on the tests conducted by the Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project. At a minimum, these tests should include specific gravity (ASTM D792 Method A or ASTM D1505), and Melt Index (ASTM D1238 (190/2.16))
- A statement that no post-consumer recycled polymer has been added to the raw resin. However, the use of clean post-industrial polymer recycled during the manufacturing process may be permitted if done with appropriate cleanliness and if recycled polymer does not exceed 5% by weight).

The Manufacturers QC documents indicating the process followed by the manufacturer to ensure that the resin supplied for the manufacture of the geomembrane delivered to the site complies with the required specifications.

The CQAO will review these documents and report any discrepancies to the Construction Manager.

HDPE RESIN PROPERTIES

Table 4: HDPE Resin Properties

Property	Units	Test Method	HDPE
Density	g/cm ³	ASTM D 1505 or D 792	0.932-0.940
Melt Index	g/10 min	ASTM D1238 Condition E	<0.8

Properties of the HDPE geomembranes

The HDPE geomembranes delivered to, and installed, on site shall be manufactured to meet the specifications ("GRI" specifications obtainable from <https://geosynthetic-institute.org/specs.htm>):

The provision and application of the scratch indication layer shall in no way effect the durability and performance of the HDPE geomembrane sheet from compliance to the specifications, as stated below.

HDPE SHEETING MATERIAL PERFORMANCE REQUIREMENTS

MATERIAL SPECIFICATION FOR HDPE GEOMEMBRANE

The material shall be in compliance with GRI-GM13 Specifications for smooth-smooth HDPE Geomembranes. The material shall comply with the following properties as set out and described in GRI-GM13 Table 1 (b) for Smooth HDPE geomembranes, and GRI-GM13 Table 2 (b) for Textured HDPE geomembranes.

Table 5: HDPE Sheeting Material Performance Requirements

Property	Test Method	QC/QA TEST FREQUENCY
Thickness	As listed in GRI-GM13	As listed in GRI-GM13
Formulated density	As listed in GRI-GM13	As listed in GRI-GM13
Tensile Properties	As listed in GRI-GM13	As listed in GRI-GM13
Puncture Resistance	As listed in GRI-GM13	As listed in GRI-GM13
Stress Crack Resistance	As listed in GRI-GM13	As listed in GRI-GM13
Carbon Black Content	As listed in GRI-GM13	As listed in GRI-GM13
Carbon Black Dispersion	As listed in GRI-GM13	As listed in GRI-GM13
OIT	As listed in GRI-GM13	As listed in GRI-GM13

A width of approximately ≥ 150 mm on the lengthwise edges of each sheet shall be left untextured for ease of seaming. The widths of the panels are to be minimum 7.0m wide to limit the number of seams required.

In addition, a minimum residual Interface Friction Angle between the Smooth-Textured GM & Overlying GTX Protection Layer of $\geq 8^\circ$ using ASTM D5321 will be required and $\geq 15^\circ$ using ASTM D5321 between the Smooth-Textured GM and the Underlying GCL.

Note that the material compliance listed in the tables above is applicable to the black/carbon-rich portion of the two-colour coextruded HDPE geomembrane i.e. testing of the geomembrane without scratch indication layer.

In addition to the above properties, the minimum thickness of the coloured scratch indication layer is to be verified using the same method as the Carbon Black Dispersion test as detailed in ASTM D5596. The thicknesses will be measured every 20 000kg of geomembrane roll production and the material shall comply with all individual values being equal to or greater than the specified minimum thickness.

5.2.2.1.6 SUBMITTALS

The GSM manufacturer shall issue Quality Control submissions to the Construction Manager/CQAO and CQA officer for each delivery of material. The submissions shall include the following information:

Prior to the shipment of any geomembrane, the Manufacturer will provide the CQAO with the following:

- A certified properties sheet including, at a minimum, all specified properties (parameters), and test methods indicated in the specifications.
- A list of quantities and descriptions of materials other than the base polymer which comprise the geomembrane; and
- The internal MQC sampling procedures, frequencies of testing, and results of testing of material supplied to the project.

The CQAO will verify that:

- The property values certified by the Manufacturer meet all of the Project specifications; and
- The measurements of properties by the Manufacturer are properly documented, the test methods used are acceptable, and the geomembrane meets the Project Specifications.
- GSM Manufacturer Tracking List - Cross-referencing list delineating the corresponding lots for the materials used in the production of the rolls delivered.
- Manufacturing Quality Control Data - The manufacturing quality control test data indicating the actual test values.
- Physical Properties Sheet - The material specification for the geomembrane supplied in accordance with this specification.
- Letter of Certification - The letter indicating that the material is in conformance with the physical properties specified.

5.2.2.1.7 TESTING

Conformance Testing will be performed and approved prior to shipment and also on arrival of material on site. Durability tests are to be conducted as soon as the material is manufactured.

The geomembrane material shall be tested by the manufacturer for compliance with the specifications. The costs of these tests are to be included for in the tendered price for Quality Control/Quality Assurance.

Conformance Testing may, at the discretion of the Construction Manager/CQAO, be carried out by an independent laboratory (QCA laboratory). Conformance testing is not an opportunity to reproduce the QC testing program. It is a check to provide confirmation that satisfactory material is delivered to the site. The name and address of the laboratory shall be approved by the Construction Manager. The Construction Manager/CQAO has the right to reject any roll or production batch if the samples do not pass the conformance testing.

5.2.2.1.7.1 IN PLANT CONFORMANCE TESTING

The purpose of In-plant Material Conformance Test Sampling is to verify that geomembrane material which is designated for the Owner's project is confirmed as meeting the project specifications prior to shipment to the site. Thus, barring a transportation accident, the geomembrane can be installed immediately when it arrives on site.

The Manufacturer will make available all necessary personnel and equipment to assist the CQAO in retrieving conformance samples of the geomembrane material.

The CQAO shall send to the CQAO Laboratory conformance samples for testing. The frequency of sampling shall be at the discretion of the CQAO but shall typically be between each 10,000 and 25,000 m² of geomembrane. No material shall be shipped to the site until conformance test results are obtained.

5.2.2.1.7.2 ON-SITE CONFORMANCE TESTING

If In-Plant conformance testing is not performed, upon delivery of the rolls of geomembrane to the site, the CQAO will ensure that samples are removed at the frequency specified in the Project Specifications and forwarded to the CQA Laboratory for GRI testing to ensure conformance to both the Project Specifications and the Manufacturer's list of guaranteed properties.

5.2.2.1.8 SAMPLING

Samples will be taken across the entire width of the roll and will not include the outer wrap of the roll. Unless otherwise specified, 10 samples across the width of the roll 300 x 300mm will be taken. Specimens for testing will be taken across the full width of the sample.

If roll numbers are very different and non-sequential, consideration should be given to testing each block of roll numbers at the same frequency.

5.2.2.1.9 TEST RESULTS

The CQAO will examine all results from laboratory conformance testing and will report any non-conformance to Construction Manager/CQAO .

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

The Manufacturer will replace the roll of geomembrane that is in non-conformance with the specifications with a roll that meets specifications.

The CQAO will remove conformance samples for testing by the CQA Laboratory from the next higher and lower numbered rolls. These two samples must both conform to specifications. If either of these samples fail, testing shall continue until the defective rolls are isolated. These rolls will be replaced by the Manufacturer, at no expense to the Owner. This additional conformance testing will be at the expense of the Manufacturer.

The CQAO will document actions taken in conjunction with conformance test failures.

5.2.2.1.10 PACKAGING AND IDENTIFICATION

All geomembrane roll cores shall be sufficiently strong to resist collapse during transit and handling. The Construction Manager/CQAO has the right to reject any roll if, upon delivery onto site, the core has collapsed or if the roll is damaged in any other way.

Before shipment, the manufacturer shall label each roll, both on the geomembrane roll and on the surface of the geomembrane or any plastic protective sleeve. Labels shall be resistant to fading and moisture degradation to ensure legibility at the time of the installation. At a minimum, the roll labels shall identify the following:

- Product Name and Grade
- Length and width of roll
- Total weight of roll,
- Production Lot number and Individual roll number

5.2.2.2 TRANSPORTATION, HANDLING AND STORAGE OF GEOSYNTHETIC LINERS

5.2.2.2.1 TRANSPORTATION AND HANDLING OF MATERIALS

The Installer shall contact the supplier before shipment to determine if the unloading methods and equipment differs from that specified below. Significant deviations from these procedures shall be pre-approved by the Construction Manager/CQAO in writing.

Geomembranes must be supported during handling to ensure worker safety and to prevent damage to the product. Under no circumstances may the rolls be dragged, lifted from one end, lifted with only the forks of a lift truck or dropped on to the ground from the delivery vehicle.

The CQA officer shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the liner material itself. Suitable handling equipment is described below:

Spreader Bar Assembly - A spreader bar assembly shall include a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the geomembrane core while the spreader bar beam will prevent chains or straps from chafing the roll edges.

Carpet Spike - A carpet spike is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment and the other end rounded off to allow easy insertion into roll material cores. If a carpet spike is used, it must be at least 3,0 m long and inserted to its full length into the roll core to prevent excessive bending of the roll when lifted.

Roller Cradles - Roller cradles consist of two large diameter rollers spaced approximately 75 mm apart, which both support the geomembrane roll and allow it to unroll freely. The use of roller cradles will be permitted if the rollers support the entire width of the geomembrane roll.

Straps - Straps may be used to support the ends of spreader bars but are not recommended as the primary support mechanism. As straps may damage the geomembrane where wrapped around the roll and generally do not provide sufficient uniform support to prevent roll bending or deformation, great care must be exercised when this option is used.

5.2.2.2.2 INSPECTION UPON DELIVERY

The CQAO shall be notified in a timely manner when delivery and unloading is to take place.

Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Possible product conditions and actions are listed below.

Rolls, including the roll cores, exhibiting damage shall be marked and set aside for closer examination during deployment. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape before being placed in storage to prevent moisture damage.

The Geosynthetic Membrane (GSM) Installer should oversee delivery and unloading and take responsibility for crushed cores that they did not identify at time of delivery.

The presence of free-flowing water within any roll packaging shall require that roll to be set aside for further examination to ascertain the extent of any damage.

Geomembrane rolls delivered to the project site shall be only those indicated on the geomembrane manufacturing quality control certificates.

The Construction Manager/CQAO reserves the right to reject any roll at any stage prior to installation should it exhibit any of the above damages or non-conformance.

5.2.2.2.3 STORAGE

Storage of the geomembrane rolls shall be the guidance of the Installer done by the Contractor. All geomembrane rolls shall be stockpiled and maintained dry in a well-drained flat location area away from high-traffic areas but sufficiently close to the active work area to minimise handling.

Rolls shall not be stacked on uneven or discontinuous surfaces, in order to prevent bending, deformation, and damage to the geomembrane or cause difficulty inserting the carpet spike

or core pipe. The rolls shall be protected from puncture, abrasion, excessive heat or cold, material degradation or other damaging circumstances.

Geomembranes shall not be stored more than four rolls high or limited to the height at which installation personnel may safely manoeuvre the handling apparatus, whichever is lowest. Stacks or tiers of rolls must be situated in a manner that prevents sliding or rolling by chocking the bottom layer of the rolls. Storage shall not result in crushing of the coves on flattening of the rolls.

An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for geomembrane material stored outdoors.

5.2.2.2.4 MARKING ON GEOSYNTHETICS

All markings on the geosynthetics shall be made with a marker that will be clearly visible and that will not harm or impede the function of the geosynthetic. Only the Lining Sub-Contractor, QCAO and the Engineer will be allowed to make any markings on the geosynthetics.

5.2.2.3 OVERVIEW OF QUALITY ASSURANCE SUBMISSIONS

5.2.2.3.1 MANUFACTURING QUALITY ASSURANCE DOCUMENTATION

Geomembrane Manufacturing Quality Assurance (MQA) sampling and testing for compliance with this specification shall be co-ordinated by the Construction Quality Assurance (CQA) officer as necessary to support the manufacturer's Manufacturing Quality Control (MQC) data.

5.2.2.3.2 SUBMISSIONS REQUIRED BEFORE SHIPMENT

Prior to shipment, the Manufacturer will furnish the CQAO with Quality Control certificates covering each roll of geomembrane and welding rod provided. (NOTE: Tests do not have to be done on each roll, they simply need to be done according to the frequency. The Quality Control certificate will be signed by a responsible party employed by the Manufacturer, preferably the QC Laboratory Manager.

The Quality Control certificates will include:

Resin Manufacturer, resin type, resin lot number, and geomembrane roll numbers; and results of Quality Control tests. At a minimum, results will be given for thickness, specific gravity/density, uniaxial tensile strength and elongation at yield and break, single point stress rupture time, and carbon black content and dispersion, evaluated in accordance with the methods indicated in the specifications or equivalent methods previously approved by the Construction Manager/CQAO and CQAO. No material will be installed until complete QC test data have been provided.

The CQAO will:

- verify that the Quality Control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls and resin related to it; and review the Quality Control certificates and verify that the certified roll properties meet the Manufacturer's and Project Specifications.

5.2.2.3.3 SUBMISSIONS REQUIRED UPON DELIVERY TO SITE

Prior to geosynthetic installation, the Construction Manager/CQAO shall review the Geosynthetic Installer's Quality Control submittals to confirm that materials meet the Construction Specifications. The CQAO shall review the following submittals for each geosynthetic material specified for the Project:

- Geosynthetic material samples, name of Manufacturer, and minimum material specifications which shall include the Manufacturer's minimum physical properties of the material, test methods (ASTM Standards) used, and factory and site seaming methods
- Manufacturer's Quality Control Manual followed during the manufacturing process
- The origin (supplier's name and production plant), identification (brand name and number) and material properties of the resin used to manufacture the product
- Geosynthetics Installer's Quality Control Manual, for the installation and testing of the geosynthetic
- A copy of each of the Quality Control Certificates on each lot of resin issued by the resin Supplier for the specific material for this project. Geomembrane submittals shall include certification of the resin for extrusion welding rod
- The result of quality control testing conducted on the resin used in manufacturing the specific material for this project
- A listing which correlates the resin to the individual geosynthetic rolls and extruded materials
- A copy of the geosynthetic roll Quality Control Certificates which shall be supplied at a minimum frequency of one (1) per every fifty thousand (50,000) square feet of geosynthetic material continuously produced and supplied to the project unless otherwise presented in the Construction Specifications
- A panel layout drawing for geomembrane showing the proposed installation layout identifying field seams as well as any variance or additional details which deviate from the Construction Drawings
- A detailed installation schedule for the project
- Certification that the extrusion welding rod to be used is comprised of the same resin type as the geomembrane to be used (geomembrane only)

5.2.2.4 GEOMEMBRANE INSTALLATION

5.2.2.4.1 SUBSURFACE PREPARATION

5.2.2.4.1.1 EARTH SUBGRADE

The Civil Contractor will be responsible for preparing the supporting soil according to the project specifications. The subgrade is to be prepared such that:

- the lines and levels of the surface are according to the drawings and specifications.
- the supporting soil meets the density specification.
- the surface to be lined has been finished so as to be free of irregularities, protrusions, loose soil, biscuit layers, desiccation cracks and abrupt changes in grade.
- the gravel surface layer (as applicable) of the supporting soil does not contain stones or other objects larger than 6mm (or that which may have been specified as maximum particle size for that adjoining layer – see earthworks specifications) which may be damaging to the geomembrane; and
- there are no areas excessively softened by high water content.
- there are no equipment tracks or footprints present on the subgrade.

The Civil Contractor is to request the CQAO's approval of the subgrade in writing. The CQAO is to inspect the subgrade to verify that it meets the specification and confirm this in writing. The Installer will certify in writing that the surface on which the geomembrane will be installed within the next 24 hr is acceptable. The certificate of acceptance will be given by the Installer to the CQAO prior to commencement of geomembrane installation in the area under consideration.

The CQAO will also acknowledge the approval of the subgrade in writing. After the supporting soil has been accepted by the Installer, it will be the Installer's responsibility to indicate to the CQAO any change in the supporting soil condition that may require repair work. If the CQAO concurs with the Installer, then the Installer will ensure that the supporting soil is repaired.

The Installer is responsible for maintaining the condition of the subgrade after approval up until the placement of the geomembrane.

5.2.2.4.1.2 GEOSYNTHETIC LAYER

Prior to the deployment of any geotextile, as well as other underlying geosynthetic materials upon which the geomembrane material may be installed, the subgrade shall be inspected and approved in writing by the CQAO and Installer.

It shall remain the responsibility of the Main Contractor to install the geotextiles in a manner such that the subgrade or other surfaces do not become disturbed and such that the composite lining system is not adversely affected either during construction or during the life of the facility. Where such disturbance does occur, the Main Contractor shall reinstate the area to conform with the requirements of this Specification.

The geotextile shall always be ballasted and anchored within anchor trenches or by using sand filled ballast bags and similar, to ensure that the geotextile is not displaced or uplifted by wind or other cause.

5.2.2.4.2 ANCHORAGE TRENCHES AND EDGE TIE-IN

5.2.2.4.2.1 ANCHOR TRENCHES

Anchor trenches will be excavated by the Civil Contractor (unless otherwise specified) to the lines and dimensions shown on the design drawings, prior to geosynthetic placement.

The edge of the trench, over which the geosynthetic membrane enters the trench, will be rounded to avoid sharp bends in the geomembrane. There shall be no sharp protrusions on the inside wall of the trench. No loose soil will be allowed to underlie the geomembrane in the trenches.

Water shall not be allowed to stand, or soften the soil, in the anchor trench. Responsibility for dewatering of the anchor trench shall reside with the Main Contractor.

The anchor trench shall be inspected as well as approved by the Construction Manager and CQAO officer before geomembrane placement, backfilling and compaction of the anchor key material.

5.2.2.4.3 GEOMEMBRANE PLACEMENT

Before any geomembrane is deployed the relevant documents must be received from the Main Contractor and be reviewed and approved by the CQAO. The textured HDPE geomembrane shall be placed with the textured surface face down (if applicable).

5.2.2.4.3.1 CONFORMANCE TESTING

Prior to geosynthetic installation, the Construction Manager/CQAO shall obtain samples of the geosynthetics for conformance testing to evaluate or confirm that these materials meet the Construction Specifications. The Construction Manager/CQAO shall mark the machine direction and roll number on the sample, and date the sample was obtained and forward the sample to the geosynthetic laboratory. All conformance tests shall be performed in accordance with the Construction Specifications. The CQA Engineer shall review the test results and shall report any non-conformance to the Construction Manager and the Installer.

5.2.2.4.3.2 FIELD PANEL IDENTIFICATION

A field panel is a single piece of geomembrane (other than a patch or cap strip) which is seamed in the field: i.e. a roll or a portion of roll cut in the field.

It will be the responsibility of the CQAO to ensure that each field panel is given an "identification code" (number or letter-number) consistent with the layout plan, which is supplied by the Installer. This identification code will be agreed upon by the Installer and the CQAO. This field panel identification code should be as simple and logical as possible. It will be the responsibility of the Installer to ensure that each field panel placed is marked with the original roll number as well as the panel identification code. The identification code and roll number will be marked at a location agreed upon by the Installer and CQAO.

Typically, panels will be numbered in the order in which they are placed. The Installer shall keep accurate records of the positions, dimensions and numbering of panels for submittal to the CQAO at weekly intervals. The CQAO will establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.

5.2.2.4.3.3 FIELD PANEL PLACEMENT

No geosynthetics shall be deployed, joined, or tested unless a representative of the Construction Manager is present to monitor such activities. Field panel placement shall not be undertaken in the presence of excessive moisture, in an area of standing water, or during high winds. The Civil Contractor shall ensure that run-off water is diverted from the area surrounding the lining installation.

The Installer will record the identification code, roll number, location, weather conditions, and date of installation of each field panel. The information shall be submitted to the CQAO on a weekly basis.

If a portion of a roll is set aside to be used at another time, the roll number shall be written on the remainder of the roll in several places.

LOCATION

The CQAO will verify that field panels and seam orientations are approximately as indicated in the Installer's approved layout plan, or as modified.

COMPENSATION FOR MATERIAL EXPANSION AND CONTRACTION

The Installer will be responsible for determining the required amount of compensation that must be installed in the geomembrane to ensure that it will not be unduly tensioned due to temperature variations in service. Such calculations shall be shown to the CQAO and Resident Construction Manager. The Installer will be responsible for ensuring that sufficient geomembrane is installed to compensate for contraction of the material during anticipated lower temperatures and to prevent expansion and excessive wrinkling at possible higher covering temperatures.

The methods of installing compensation will be discussed with, and approved by, the Construction Manager and the CQAO.

The geomembrane must not be tensioned and must be fully supported by the subgrade when it is covered by soil or liquid ballast.

INTIMATE SUBGRADE CONTACT

Only that amount of geomembrane will be deployed in one day that can be covered by the required thickness of the protection layer (geocell with soilcrete infill) in the following day. The Protection layer will be placed as described in this document and the project specification document. Any area of geosynthetic placed that is not covered is to be adequately ballasted with sand bags to prevent damage by the wind.

The CQAO will monitor the placement of geomembrane and protection layer to confirm that the geomembrane is essentially in complete contact with the GCL at the end of the working day, and is restrained in this position, without excessive tension, by the peripheral soil.

The CQAO will monitor the placement of the protection layer at the start of the first shift of the next day to confirm that no standing or folded wrinkles in the geomembrane are covered by the protection layer. The geomembrane must be in intimate contact with the GCL.

At all times the exposed edges of geosynthetics will be kept clean and protected from damage.

A minimum of five thickness measurements shall be taken along the edge of each panel width and at least two thickness measurements shall be taken along each panel length. For smooth geomembrane, thickness shall be measured in accordance with ASTM D 5199. For textured geomembrane, thickness shall be measured in accordance with ASTM D 5994. If thickness readings fall below the values specified in Table [1] [2] [4], the entire panel shall be rejected and replaced. The Installer shall provide the appropriate apparatus for thickness measurements.

INSTALLATION SCHEDULE

Field panels will be placed one at a time, and each field panel will be seamed immediately after its placement (in order to minimize the number of unseamed field panels exposed to wind).

It is beneficial to "shingle" overlaps in the downslope direction to facilitate drainage in the event of precipitation, shingling should also be done in the downstream direction to minimize resistance to flow. It is also beneficial to proceed downslope and in the direction of (with) prevailing winds. Scheduling decisions must be made during installation, in accordance with varying environmental conditions. In any event, the Installer will be fully responsible for the decisions made regarding placement procedures.

The CQAO will evaluate every change in the schedule proposed by the Installer and advise the Construction Manager on the acceptability of that change. The CQAO will verify that the condition of the supporting soil is still satisfactory for installation of geomembrane.

WEATHER CONDITIONS

Geomembrane placement will not proceed at geomembrane temperatures below 0°C or above 75°C unless approved by the Construction Manager.

Geomembrane placement will not be done during any precipitation, conditions with excess moisture (e.g. fog, dew) in an area of ponded water, or during excessive winds except as approved in an Action Decision Meeting.

NOTE: The only temperature of significance is the actual geomembrane temperature, not the ambient temperature. When exposed to sunlight the geomembrane temperature will be significantly higher than ambient.

The CQAO will verify that the above conditions are observed. Additionally, the CQAO will verify that the supporting soil has not been damaged by weather conditions.

The CQAO will inform the Construction Manager if the above requirements are not observed.

GEOMEMBRANE PLACEMENT

The Installer shall be responsible to ensure that:

- Equipment used does not damage the geomembrane as a result of handling, trafficking, excessive heat, leakage of hydrocarbons, or by other means.
- Any All-Terrain Vehicles (ATVs) if used to deploy geosynthetics exert ground pressures less than 55 kPa (8 psi).
- ATVs are not operated: 1) at excessive speeds, 2) in tight turning circles, 3) under extreme braking and accelerating conditions, 4) with dirty tires, and 5) over wrinkles, that might damage the geomembrane.
- The prepared surface underlying the geomembrane has not deteriorated since previous acceptance and is still acceptable immediately prior to geomembrane placement.
- Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.
- Personnel working on the geomembrane do not smoke, do not wear hard-soled shoes, and do not engage in activities which could damage the geomembrane.
- Frequently used pathways up and down geomembrane on slopes are protected by a roll of geotextile.
- The methods used to unroll the panels do not cause excessive scratches or crimps in the geomembrane and do not damage the supporting soil.
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels).
- Geomembrane is not allowed to unroll freely down a slope.
- Geomembrane is not placed under tension, unless approved by the Construction Manager in writing.
- Adequate temporary loading and/or anchoring (e.g., sandbags, tires), that does not damage the geomembrane, has been placed to prevent uplift by wind.
- Direct contact of equipment with the geomembrane shall not be allowed, except as previously described for ATVs used to deploy geosynthetics. The geomembrane shall be protected by geotextiles, extra geomembrane, soil layers, or suitable materials, in areas where equipment may be used, or traffic may be expected.
- Only hook bladed utility knives are used to cut through the geomembrane.
- Appropriate care is to be taken to prevent shock and explosions caused by static electricity discharges.
- All handholds cut for moving panels and damage caused by clamps are repaired.
- Panels are not moved such that subgrade soil can peel the underside seam flap.
- Motorized equipment contacts and /or traffic shall not be allowed on the liner.
- Portable generators may be positioned on the lined area provided that the liner is protected by an adequate cushion of geotextile or an additional layer of liner material.
- The Installer shall not refuel generators or other equipment that uses petroleum products while the equipment is located on the liner.
- Equipment shall be maintained such that no petroleum products come into contact with the liner.
- No equipment or tools shall damage the liner by handling, traffic, or by other means.
- Use of metal tools shall be kept to a minimum.
- Trial seams and testing does not take place directly on installed geosynthetics.

The CQAO will inform the Construction Manager if the above requirements are not observed.

TEMPORARY BALLASTING

Temporary ballasting around the edges of the installed liner shall be done with sandbags or equivalent non-damaging ballast material (e.g. tires without reinforcing wires exposed). Sandbags shall be of a size and weight so as to enable handling by one person and shall be spaced to provide adequate uplift protection against typical winds that might reasonably be expected to occur prior to the addition of adjacent panels or prior to permanent ballasting. Sandbags temporary anchoring a liner down a slope shall be tied with a rope, anchored in the anchor trench.

DAMAGE

The CQAO will visually examine each panel, after placement and prior to seaming, for damage.

The CQAO will advise the Construction Manager which panels, or portions of panels, should be rejected or repaired. Damaged panels or portions of damaged panels, which have been rejected will be marked, and their removal from the work area recorded by the CQAO.

At a minimum, the Installer will be responsible to ensure that:

- each panel is placed in such a manner that it has not been, or is unlikely to be, damaged; and
- any tears, punctures, holes, thin spots, and damaging inclusions, gouges, and protuberances etc., are marked for repair and brought to the attention of the CQAO.

5.2.2.4.4 FIELD SEAMING

5.2.2.4.4.1 SEAM LAYOUT

The Installer will provide the Construction Manager and the CQAO with a proposed panel layout drawing at least 15 working days prior to the commencement of installation activities. The CQAO will review the panel layout drawing and verify that it is consistent with the accepted state-of-practice and this CQA Plan. The layout shall be such as to keep the number and length of field seams to a minimum. No panels may be seamed in the field without the Construction Manager's representative's written approval. In addition, panels that significantly change the layout drawing (e.g. that change the orientation of seams) shall not be installed without the Construction Manager's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented up and down, not across, the slope. In corners and other geometrically complex locations, the number of seams should be minimized. No base seam or tee seam will be less than 2 m from the toe of slopes, or areas of potential stress concentrations, unless otherwise authorized by the Construction Manager in writing. Horizontal and T-shaped seams shall not be placed on slopes.

If roll end seams are unavoidable on slopes, the upslope panel shall overlap the downslope panel and adjacent panel cross-seams shall be staggered by at least 2 m.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Resolution Meeting.

Seams are usually identified by the panel numbers on each side, e.g. seam 1 / 2, for the seam between panels 1 and 2.

Welding is to extend at least 500mm beyond the crest and into the anchor trench.

5.2.2.4.4.2 SEAMING EQUIPMENT AND PRODUCTS

Approved methods for field seaming are thermal fusion (hot wedge, hot air, or combination) seaming and extrusion seaming. Proposed alternate methods will be documented and submitted with the tender. Only apparatus that has been specifically approved by make and model will be used. The Installer will use appropriate measuring equipment to ensure that required temperatures are being achieved.

FUSION SEAMING (Wedge-Welding)

Seaming equipment shall comply with the requirements of GRI Test Method GM 19 and all equipment used shall comply with national regulations and statutory requirements on accident prevention.

The fusion seaming machines will be equipped with gauges giving hot wedge temperatures. Temperature, speed, and nip roll pressure settings will be verified by the Installer prior to each seaming period. Nip roll and wedge geometries shall be such as to minimize residual stresses at the edge of the seam, i.e. to minimize reduction in stress cracking resistance of the geomembrane.

The Installer will log ambient conditions, geomembrane temperatures, seaming apparatus temperatures and speeds, equipment serial number, and operator initials.

The Installer is responsible to ensure that:

- The number of operable seaming machines decided at the Resolution Meeting are maintained on site at all times;
- equipment used for seaming does not damage the geomembrane;
- for tee seam intersections, all edge flaps are cut back to the edge of the outer-most peel-tested track of the seam prior to seaming;
- electric generators and fuel containers are placed on a smooth drip tray such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage;
- the geomembrane is protected from damage in heavily-trafficked areas; and
- build-up of moisture or dirt between the sheets is prevented. To accomplish this a movable protective layer may be used directly below each overlap of geomembrane that is to be seamed.

EXTRUSION SEAMING

Extrusion welding shall be used only at areas which cannot be welded by using fusion seaming.

Extrusion-seaming apparatus will be equipped with gauges giving the relevant temperatures of the apparatus such as the temperatures of the extrudate, nozzle, and preheated air.

The Installer will provide documentation (including QC certificates) regarding the welding rod or resin pellets to the CQAO, that show that the resin is the same HDPE resin as the geomembrane itself. Other seaming resins must be approved by the CQAO.

The Installer will log apparatus temperatures, extrudate temperatures, ambient conditions, and geomembrane temperatures at appropriate intervals.

The CQAO will verify that:

- the Installer maintains on-site the number of operable seaming machines decided at the Resolution Meeting are maintained on site;
- equipment used for seaming will not damage the geomembrane;
- the extruder is purged prior to seaming until all heat-degraded extrudate has been removed from the barrel and disposed in a container and not discarded on site;
- feed resin is maintained clean and dry;
- the electric generator and fuel containers are placed on a smooth drip tray such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

5.2.2.4.4.3 SEAM PREPARATION

The Installer is responsible to ensure that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, foreign material, and any mechanical damage;
- if seam overlap grinding is required, the process is completed according to the Manufacturer's instructions but within 30 minutes of the seaming operation, and in a way that does not damage the geomembrane;
- the abrading does not remove more than 10 percent of the thickness of the geomembrane, and the resulting abrasion marks are covered by the finished extrusion bead;
- any visible abrasion marks, after seaming, are essentially perpendicular to the direction of the seam;
- the abrading does not introduce damaging gouges in the geomembrane; and
- seams/panels are aligned with a minimum of wrinkles and "fishmouths".

5.2.2.4.5 WEATHER CONDITIONS FOR SEAMING

The following protocols will be observed during seaming:

- Unless authorized in writing by the Construction Manager, no seaming will be attempted at geomembrane temperatures below -0°C or above 75°C.
- Below a geomembrane temperature of 5°C, the need for pre-heating and additional testing should be discussed with the Construction Manager and CQAO.
- In all cases, the geomembrane in the seaming area will be dry and protected from wind and airborne particulates.

- Geomembrane temperatures will be measured with a surface temperature thermocouple or a calibrated infrared pyrometer.
- Care shall be taken that wind chill does not reduce the geomembrane temperature such that fusion is inadequate or that excess heat is being used to overcome the wind chill.

If the Installer wishes to use methods which may allow seaming at geomembrane temperatures below 0°C or above 75°C, the Installer will demonstrate (by testing trial seams) that such methods produce seams which are entirely equivalent to seams produced at geomembrane temperatures above 0°C and below 75°C, and that the overall quality of the seam and durability of the geomembrane are not adversely affected. In addition, the Installer will prepare written certification that states that the seaming procedure does not cause any physical or mechanical modification to the geomembrane that will generate any short or long-term damage to the geomembrane liner.

The CQAO will verify that these requirements are observed and will advise the Construction Manager if potential problems are perceived. The Construction Manager will then decide if the seaming will be stopped or postponed. Such decisions may be the subject of an Action Decision Meeting.

Seaming shall not take place during precipitation, conditions of excess moisture (e.g. fog, dew), or excessive wind.

5.2.2.4.5.1 OVERLAPPING AND TEMPORARY BONDING

The Installer is responsible to ensure that:

- the panels of geomembrane have an overlap of approximately 100 mm, sufficient to allow peel and shear tests to be performed on the inner track of the seam;
- there is a free flap at the edge of the top geomembrane a minimum of approximately 10 mm wide, to allow a peel and shear test to be performed on the outer track of the seam;
- no solvent or adhesive is used unless the product is approved in writing by the Construction Manager (samples must be submitted to the Construction Manager for testing and evaluation);
- any procedure used to temporarily bond adjacent panels together does not damage the geomembrane. In particular, the temperature of hot air at the nozzle of any spot seaming apparatus will be controlled such that the geomembrane is not damaged. "Damage" includes a loss in durability; and
- temporary bonds do not interfere with the ability to perform shear and peel tests on the actual production seam.

The CQAO will log all relevant temperatures and conditions and will log and report any non-compliance to the Construction Manager.

If protective layers of geomembrane are placed on the barrier layer geomembrane for any purpose (e.g. puncture protection in drainage trenches), they shall not be tack or spot welded to the barrier layer. They shall be fully welded, except a small pressure relief segment, along the complete periphery of the protective layer or they shall not be welded at all.

5.2.2.4.5.2 TRIAL SEAMS

Trial seams will be made by each machine/operator combination on strips of HDPE geomembrane to verify that seaming can be successfully performed. Trail seams shall be made under the same surface and environmental conditions as the production seams. Such trial seams will be made at the beginning of each seaming period (i.e., at the beginning and middle of each working shift), but at least once every five hours or as requested by the Construction Manager or CQAO, for each seaming apparatus/operator combination used in the seaming period. In addition, a new trial seam will be conducted when a welding apparatus has been restarted after being switched off. A trial seam will also be made in the event that the geomembrane temperature changes more than 25°C since the last passing trial seam. When geomembrane temperatures are below 5°C or higher than 75°C more frequent trial seams may be required. In general, trial seams will be conducted as follows:

The trial seam sample will be at least 1.5 m long by 0.3 m wide with the seam centred lengthwise. The CQAO will observe all trial seam procedures.

All trial seams shall be conducted under the same conditions as will be encountered during actual seaming.

Four specimens, each 25 mm wide and a minimum of 150 mm long, will be cut from the centre section of the trial seam sample by the Installer. Two specimens will be tested in shear and two in peel using a calibrated field tensiometer (supplied by the Installer). They should meet project specifications. If any specimen fails, the entire operation will be repeated. If the second trial seam fails, the seaming apparatus and seamer will not be approved for production seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. If no subsequent machines can successfully seam the material, then the material roll shall be rejected.

The remainder of the successful trial seam samples will be assigned a number and marked accordingly by the Installer, who will also log the date, time, geomembrane temperature, number of seaming unit, settings, name of seamer, and pass or fail description. The CQAO shall inspect trial seams for uniformity and general appearance.

A trial seam shall also be prepared by each seaming machine/operator at the completion of seaming each day to determine whether changes in seam quality might have occurred during the last part of the seaming period.

No seaming equipment will be allowed to perform production welds until equipment and operators have successfully completed trial seams as witnessed by CQAO. Once the seaming process has been qualified by successfully passing a trial weld, seaming technicians shall not change parameters without performing another trial seam.

5.2.2.4.6 GENERAL SEAMING PROCEDURE

Unless otherwise specified, the general seaming procedure used by the Installer will be as follows:

- For fusion seaming, a movable protective layer of plastic may be placed directly below each overlap of geomembrane that is to be seamed. This is to help prevent any moisture build-up between the sheets to be seamed.
- If required, a firm substrate may be provided by using a flat board, or other similar hard surface placed directly under the seam overlap.

- Fish mouths or wrinkles at the seam overlaps will be cut along the peak of the wrinkle in order to achieve a flat overlap. The cut fish mouths, or wrinkles will be seamed and any portion where the overlap is inadequate will then be patched with an oval or round patch of the same geomembrane material extending a minimum of 150 mm beyond the cut in all directions. The end of the cut should be rounded.
- If seaming operations are carried out at night, adequate illumination will be provided.
- Seaming will extend at least 0.5m into the material in the anchor trench.
- Each seam will be labelled with the seaming machine number, the operator's initials, machine temperature and speed settings, date, time, direction seamed and each geomembrane panel's temperature.

The CQAO will monitor the above seaming procedures and will inform the Construction Manager of any unsatisfactory deviations from standard practice.

5.2.2.4.6.1 T-JOINTS

T-joints are formed where a longitudinal seam is intersected by another seam. T-joints shall be staggered between panels to avoid the formation of cross joints.

T-joints shall be constructed so as to ensure the watertightness of the point where the two seams intersect. The procedure for forming a hot-wedge seamed T-joint shall be as per SANS 10409:2005, Clause 10.4.4.4, with the inclusion of 10.4.4.4(g).

5.2.2.4.6.2 NON-DESTRUCTIVE SEAM CONTINUITY TESTING

CONCEPT

The Installer will non-destructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), spark test, or other approved method. The purpose of non-destructive testing is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of all field seaming. Non-destructive testing will not be permitted unless there is, in the opinion of the CQAO, adequate illumination.

The CQAO will:

- observe all non-destructive testing,
- record location, date, test unit number, operator, and outcome of all testing
- mark the seams (on the geomembrane) that have been tested; and
- log and inform the Installer and Construction Manager of any required repairs.

The Installer will complete any required repairs.

The CQAO will:

- observe the repair and re-testing of the repair;
- mark on the geomembrane that the repair has been successfully made and tested; and
- document the results.

The following procedures will apply to segments of seams that cannot be non-destructively tested:

- All such seam segments will be cap-stripped with the same type of geomembrane material, or
- All such seam segments will be very carefully prepared and welded by the master seamer under the observation of the CQAO.
- If the seam is accessible to testing equipment prior to final installation (e.g. after prefabrication), the seam will be non-destructively tested prior to final installation.
- The seaming and cap-stripping operations must be observed for proper procedures by the CQAO and Installer's QC representative.

The Installer will write the details of each seam non-destructive test on the geomembrane with a permanent marker. For air pressure tests this will include the initials of the tester, the date, start time and pressure, end time and pressure, and pass or fail result. For vacuum testing this will include the initials of the tester, the date, and pass or fail result. For spark testing this will include the initials of the tester, the date, voltage setting, and pass or fail result. When a test fails, the number of the appropriate repair will also be recorded on the geomembrane.

SUBMITTALS

Prior to any non-destructive testing, the Installer shall submit to the CQAO calibration certificates for all pressure gauges to be used during vacuum and air pressure testing or shall otherwise demonstrate that all gauges are in satisfactory working condition.

Vacuum Box Testing

The equipment will be comprised of the following:

- a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole, valve assembly, and a vacuum gauge;
- a vacuum tank and pump assembly equipped with a pressure controller and pipe connections;
- a pressure/vacuum hose with fittings and connections;
- a soapy solution that does not cause environmental stress cracking in the geomembrane, and
- a soap solution applicator.

The following procedure will be followed:

- for fusion seams (not normally tested with a vacuum box), cut off the free flap with an approved cutter (so that the lower geomembrane is not damaged) prior to testing the seam;
- energize the vacuum pump and reduce the tank pressure to approximately 35 kPa gauge;
- with a soapy solution, wet a strip of geomembrane which is wider and longer than the vacuum box;

- place the box over the wetted area;
- close the pressure relief valve and open the vacuum valve;
- ensure that a leak-tight seal is created;
- examine the geomembrane seam through the viewing window for the presence of soap bubbles (large bubbles, or fine froth) for a period of not less than 5 seconds;
- if no bubbles or foam appear after 5 seconds, close the vacuum valve and open the pressure relief valve. Move the box over to the adjoining section of seam, with some overlap, and repeat the process;
- all areas where soap bubbles appear will be marked and repaired; and
- excess soap solution shall be cleaned or rinsed off the geomembrane and seam.

Air Pressure Testing

The following procedures are applicable to those seaming processes which produce a double track seam with a central channel.

The equipment will be comprised of the following:

- an air pump equipped with a pressure gauge capable of generating and sustaining a pressure between 160 and 280 kPa mounted on a cushion to protect the geomembrane;
- a pressure hose with fittings and connections;
- a sharp hollow needle, or other approved pressure-feed device attached to a pressure gage; and
- clamps or other devices to seal the ends of the seam to be tested.

The following procedures will be followed:

- seal both ends of the seam to be tested;
- insert the pressure-feed device into the channel of the seam;
- energize the air pump to a pressure between 185 and 275 kPa (depending on geomembrane thickness), close the valve, and allow the temperature of the air in the channel, and thus the pressure, to stabilize for about 2 minutes;

Table 6: Air Channel Test Pressures for HDPE Geomembranes

Geomembrane Thickness	Minimum Pressure	Maximum Pressure
(mm)	(kPa)	(kPa)
1.0	165	240
1.5	185	275
>2.0	205	275

- Verify that the stabilized pressure is within the required range and note the pressure loss after a further 5 minutes. If loss of pressure exceeds the amount indicated in Table 10, or if the pressure does not stabilize, locate the faulty area and repair it.

Table 7: Allowable Pressure Loss In Air Channel Test

Geomembrane Thickness	Maximum Allowable Pressure Drop
(mm)	(kPa)
1	28
1.5	21
>2.0	14

- Verify that the full length of the seam section has been tested by observing the air pressure gauge for a decrease in pressure when the seal at the end of the channel away from the air pump is removed, or by visual inspection of the pressurised channel. If there is a blockage in the channel, the entire seam must be capped, with cap seams being non-destructively tested, or the location of the blockage must be found and the untested part of the seam must be properly tested; and
- Remove the needle or other approved pressure-feed device and seal the hole.

NOTE: A decrease in the geomembrane temperature (e.g. due to clouds) will also cause a reduction in air channel pressure.

Spark Testing

Spark Testing shall be performed according to ASTM D6365 for short, detail (e.g. sump, penetration) extrusion welds that cannot be tested by vacuum box testing. It may also be used on long extrusion seams as the primary non-destructive test method.

It is recognized that this test requires no signal be generated for a passing result. There are many conditions in addition to adequate seaming under which no signal will be generated: proper connections may not be made, the voltage may be set too low, the search electrode may be held too far away. Thus, this test method may only be used where no other non-destructive test method can be applied. Written approval must be obtained from the Construction Manager to perform this test and the CQAO must be informed and present during testing.

Visual Examination

Air pressure, vacuum box, and spark testing methods apply only to seams. Installer and CQA personnel shall continuously visually examine the geomembrane panels for the presence of other penetrating and non-penetrating defects and shall continuously feel for protuberances when walking on the geomembrane.

The Installer shall inform the CQAO in writing and verbally of any penetrating or non-penetrating defects that he, his staff or anyone else may observe. Failure to do so will be seen in a very negative light by the Construction Manager.

Visual examination should take advantage of low angles of sunlight and early morning condensation on the geomembrane.

Immediately prior to covering, the geomembrane, seams, and non-seam areas shall be visually inspected by the QCAO and Installer for defects, holes, or damage due to weather conditions or construction activities. At the QCAO's discretion, the surface of the geomembrane shall be brushed, blown, or washed by the Installer if the amount of dust, mud, or foreign material inhibits inspection or functioning of the over lying material. Each suspect location shall be non-destructively tested. Each location that fails non-destructive testing shall be repaired accordingly.

5.2.2.4.6.3 DESTRUCTIVE TESTING

CONCEPT

Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam bond strength and the effects of seaming on the adjacent geomembrane. Seam strength testing will be done as the seaming work progresses, not at the completion of seaming.

LOCATION AND FREQUENCY

The CQAO will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows:

A minimum frequency of one sample for every 150 m of seam made by each extrusion machine/operator combination - unless a different frequency is requested by the Construction Manager or CQAO.

Conditions under which testing frequency may be increased or decreased as the project progresses will be agreed upon by the Installer and CQAO at the Resolution Meeting.

Test locations will be determined during seaming at the CQAO's discretion. Selection of such locations may be prompted by suspicion of overheating, contamination, offset seams, or any other evidence of imperfect seaming.

If trial seams are not made at the end of the day, one sample for destructive testing shall be removed from the last seam made by each seaming machine at the end of each working day.

The Installer will not be informed in advance of the locations where the seam samples will be taken.

Test frequencies may be increased or decreased at the CQAO's discretion depending on the consistency of the test results.

SAMPLING PROCEDURE

Samples will be cut by the Installer as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The CQAO will:

- observe sample cutting;
- assign a number to each sample, and mark it accordingly; and
- record the sample location on the layout drawing.

All holes in the geomembrane resulting from destructive sample removal will be immediately repaired.

SIZE OF SAMPLES

At a given sampling location, two types of samples will be taken by the Installer.

First, two pairs of specimens for field peel and shear testing will be taken. Each of these specimens will be 25 mm wide by at least 150 mm long, with the seam centred across the width. The distance between these two pairs of specimens will be 1.1 m. If both pairs of specimens pass the field tests, a sample for laboratory testing will be taken.

The sample for laboratory testing will be located between the two pairs of specimens taken for field testing. Unless determined otherwise at the Resolution Meeting, the destructive sample will be 0.3 m wide by 1.1 m long with the seam centred lengthwise. The sample will be cut into three parts and distributed as follows:

- one portion, measuring 0.3 m x 0.5 m, to the Installer for QC laboratory testing;
- one portion, measuring 0.3 m x 0.3 m, to the CQAO for CQA Laboratory testing.
- one portion, measuring 0.3 m x 0.3 m, to the CQAO for client archive.

FIELD TESTING

The 25 mm wide specimens will be tested in the field, by calibrated gauged tensiometer, one of each pair in peel and one in shear. If any field test specimen fails to pass the criteria and the project specifications, then the procedures outlined in Non-destructive Seam Continuity Testing will be followed.

The CQAO will witness all field tests and mark all samples and portions with their unique sample number. The CQAO will also log the date and time of sampling, and test pass or fail description.

If the two pairs of specimens meet the project specifications, the sample qualifies for testing in the laboratory; if they fail, the seam should be repaired.

CONSTRUCTION QUALITY ASSURANCE LABORATORY TESTING

Destructive test samples will be packaged and shipped to the CQAO laboratory by the CQAO, in a manner which will not damage the test sample. The Construction Manager will verify that packaging and shipping conditions are acceptable. The Construction Manager will be responsible for storing the archive samples. This procedure will be fully outlined at the Resolution Meeting. Test samples will be tested by the CQAO Laboratory.

Testing will follow ASTM D4437 as modified in NSF 54 Appendix A (1993), but with no requirement for sample conditioning time. The minimum acceptable values to be obtained in these tests

are those indicated in the Table 11. Five specimens will be tested in peel and five in shear. Specimens will be selected alternately by test from the samples (e.g., peel, shear, peel, shear, etc.). The CQAO will review laboratory test results as soon as they become available and make appropriate recommendations to the Construction Manager.

INSTALLER'S LABORATORY TESTING

The Installer's laboratory test results will be available to the Construction Manager and the CQAO for review.

DESTRUCTIVE SAMPLE PASS/FAIL CRITERIA

The criteria shown in Table 11, must be met for the acceptance of peel and shear test specimens:

Table 8: Seam Specimen Test (ASTM D4437) Specifications

PEEL TEST	CRITERIA
Peel Strength	>70% (fusion seam), >65% (extrusion seam) minimum specified geomembrane yield strength*
Seam Separation	<10% of originally bonded area
SHEAR TEST	
Shear Strength	>95% minimum specified geomembrane yield strength*
Elongation	>100% of distance between edge of seam and nearer grip
Location of Failure	Outside the weld

* The yield strength specified by the Manufacturer, which is usually the population average value less 2 standard deviations.

The peel criteria apply to both tracks of double track seams. Nine out of the ten specimens in a seam destructive sample must meet the criteria above for acceptance of the complete destructive sample.

The CQAO will ensure that the CQA Laboratory retains all sample and specimen remnants, clearly labelled, for at least 30 days after the last specimen for the project has been tested.

PROCEDURES IF DESTRUCTIVE SAMPLE FAILS

The following procedures will apply whenever a sample fails a destructive test, whether that test is conducted by the CQA Laboratory, the Installer's laboratory, or on the field tensiometer. The Installer has two options:

Reconstruct the seam between the nearest passing destructive test locations on each side of the failed sample; or

Trace the seaming path to an intermediate location (3 m minimum from the failed test location in each direction) and take a small sample for an additional field test at each location. If these additional samples pass tensiometer testing, then full destructive test samples should be taken. If these laboratory destructive test samples pass the tests, then the seam should be reconstructed between these locations by capping. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

If a fusion-type seam fails destructive testing and the Installer chooses to repair the seam, the described method should be followed. Applying topping (bead of extrudate) is not an approved method of capping any seam unless it can be shown that this procedure will not reduce the stress rupture resistance of the seam below 75% of that of the parent geomembrane.

Only seams bounded by two locations from which samples passing laboratory destructive tests have been taken will be considered acceptable. An additional destructive test sample will be taken from repair seams when the length of a reconstructed seam exceeds 50 m. This sample must pass destructive testing, or the procedure outlined in this section must be repeated.

5.2.2.5 THE CQAO WILL DOCUMENT ALL ACTIONS TAKEN IN CONJUNCTION WITH DESTRUCTIVE TEST FAILURES, DEFECTS AND REPAIRS

5.2.2.5.1 IDENTIFICATION

All seams and non-seam areas of the geomembrane will be examined by the Installer and the CQAO for identification of defects, protruding and penetrating objects, lack of subgrade support, overheating, overgrinding, holes, blisters, undispersed raw materials, scratches and gouges, and any sign of contamination by foreign matter. To facilitate the examination the geomembrane surface will be kept clean by the Installer (or as agreed at the Resolution Meeting).

5.2.2.5.2 EVALUATION

Each suspect location, both in seam and non-seam areas, will be non-destructively tested using an appropriate method, such as vacuum box testing. Additional methods, such as electrical methods and infrared thermography, may also be used. Each location which fails the non-destructive testing will be marked by the CQAO and repaired by the Installer. Work will not proceed with any materials which will cover locations that have been repaired until passing destructive and non-destructive test results have been obtained on the repairs.

5.2.2.5.3 REPAIR PROCEDURES

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be agreed upon between the Construction Manager, Installer, and CQAO at the Resolution Meeting or at an Action Decision Meeting. The procedures available include:

- patching, used to repair all penetrating holes, tears, undispersed raw materials, and contamination by foreign matter;

- spot beading, used to repair small surface scratches, or other minor, localized non-penetrating flaws;
- capping with a strip of geomembrane, used to repair long lengths of failed seams;
- lip extrusion, an extrusion weld applied along the lip of the overlap of wedge welded seams;
- removal and replacement of a defective seam with new material that is wedge welded into place.

In addition, the following provisions will be satisfied:

- surfaces of the geomembrane which are to be repaired will be abraded no more than 30 minutes prior to the repair;
- all surfaces must be clean, free of all particulate matter, and dry at the time of the repair;
- all seaming equipment used in repairing procedures must be approved;
- the repair procedures, materials, and techniques will be approved in advance of the specific repair by the CQAO in writing;
- patches and caps will extend at least 150 mm beyond the edge of the defect, and all corners of patches will be rounded with a radius exceeding 75 mm;
- the geomembrane below large caps should be appropriately cut to avoid fluid entrapment between the two sheets and resultant pressure increases (that stress the seams) as the liner is covered;
- sharp ends of slits and cuts in the geomembrane should be rounded before patches are placed over them; and
- no more than one extrusion bead at any location will be used to make a repair - multiple beading (more than two beads at any one location) is not permitted and must be replaced with a patch.

5.2.2.5.4 VERIFICATION OF REPAIRS

Each repair will be numbered and logged. Each repair will be non-destructively tested using one of the methods described or another method approved in writing by the Construction Manager. Repairs that pass the non-destructive test will be considered acceptable. Large caps may be of sufficient extent to require destructive testing, at the discretion of the CQAO. Failed tests will require the repair to be redone and retested until a passing test results. The CQAO should observe all non-destructive testing of repairs and will record the date of the repair and test result.

No repair shall be undertaken without the CQAO being informed of the repair both in writing and verbally at least 1 day prior to the repair taking place.

5.2.2.5.5 LARGE WRINKLES

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane is completed) and prior to placing overlying materials, the CQAO will observe the sizes and distribution of geomembrane wrinkles. The CQAO will discuss with the

Construction Manager which wrinkles should be cut and re-seamed by the Installer at his cost. The seam thus produced will be tested like any other seam.

The wrinkle height to width ratio for the installed geomembrane shall not exceed 0.5. In addition, geomembrane wrinkles shall not exceed 150mm in height. Wrinkles that do not meet the above criteria shall be cut out and repaired in accordance with the Installer's approved QC manual.

5.2.2.5.6 BRIDGING OF GEOMEMBRANE

Bridging or trampolining of the geomembrane shall be considered unacceptable. Compensating material will be installed at these locations. The geomembrane must be fully supported by the subgrade at the time of covering with soil or liquid.

Closure joints and closure welds/tie-in welds should be done first thing in the morning after completing the trial welds to ensure that geomembrane is still in its contracted state. This practical guideline assists with minimizing the effect of trampolining.

5.2.2.5.7 GEOMEMBRANE ANCHORING

The periphery of the geomembrane is to be anchored in an anchor trench.

The geomembrane will not be placed on loose soil in the anchor trench. The geomembrane must be permanently anchored in the anchor trench, as soon as possible after installation, particularly in windy and/or wet environments. However, the geomembrane must be allowed to go through one cold cycle (overnight) to evaluate the potential for contraction and trampolining. The geomembrane must lie flat against the anchor trench front wall and floor. It must not be folded.

5.2.2.6 NON-GEOSYNTHETIC LAYER PLACEMENT

Construction observation and monitoring required during the placement of the non-geosynthetic layer include:

Verification that all pre-construction testing has been performed and that laboratory test results indicate compliance with the Construction Specifications. The CQAO shall assure that the Construction Manager and the Contractor receive prompt notification of material conformance,

Verify that the material upon which the non-geosynthetic layer will be placed has been installed in accordance with the Construction Drawings and Specifications, and that all required testing, and as-built documentation have been completed.

Observe and document that end tipping is the only method used to when backfilling material for gravel materials, and appropriate light ground pressure equipment (exert ground pressures less than 55 kPa (8 psi)) is used for handling the gravel material. No heavy machinery is to be used when handling gravel material.

No mechanical plant is to operate directly over geosynthetic layers.

Visually observe the gravel and sand materials to inspect for any variability in the material including variation in gradation, excess fines, or any deleterious material present (where applicable),

Verify that the CQA Survey has been completed and that the Record Drawings furnished by the surveyor indicates compliance with the lines, grades, elevations, and tolerances as indicated by the Construction Drawings and Specifications.

If the equipment or gravel/ non-geosynthetic layer placement procedures do not comply with the Construction Specifications, the geomembrane shall be exposed and inspected for potential damage, at a cost to the Contractor.

5.2.2.7 APPURTENANCES

The installation of the geomembrane in appurtenance areas and connections of geomembrane to appurtenances shall be done according to the drawings.

These cannot normally be tested by destructive or non-destructive methods, yet they can be a critical weak link in the effectiveness of the geomembrane liner. They are therefore technique and workmanship dependent and the following procedures are to be followed:

- the precise technique shall be discussed at a site meeting and drawn on paper before commencement.
- the work shall be observed by the CQAO who shall probe test the welds if appropriate prior to approval.
- Consideration in critical work should be given to the incorporation of earthing mechanisms to facilitate high voltage spark testing. This shall be discussed at a site meeting.

The Installer is responsible to ensure that:

- extreme care is taken while seaming around appurtenances, since neither non-destructive nor destructive testing may be feasible in these areas; and
- the geomembrane is supported as well as can be expected at appurtenances.

The CQAO will inform the Construction Manager if the above conditions are not fulfilled.

5.2.2.8 COVER MATERIAL

The cover materials shall be compatible as well as suitable for use over the geomembrane and be in compliance to the specification of the subgrade material (where applicable) and placed in a manner appropriate to the particular subgrade. Regardless of the cover material, the uncovered edge of geomembrane panels shall be protected at the end of the working day with a waterproof sheet, which is adequately secured with ballasts.

5.2.2.8.1 GEOSYNTHETIC FOR PROTECTION

Precaution shall be taken to prevent damage to the geomembrane by restricting the use of heavy equipment over the liner system. Installation of any overlying geosynthetic component (protection, geotextile or geocell) shall be done using either manual labour or lightweight,

rubber-tired equipment such as a 4 –wheel all-terrain vehicle (ATV). This vehicle can be driven directly on the geomembrane, provided the ATV makes no sudden stops, starts, or turns. If such occurrences do occur, the CQAO shall be notified immediately. The CQAO shall then inspect the possible damage and may instruct a repair. No other mechanical plant shall ride on the geomembrane.

HDPE may be unrolled with the use of low ground pressure equipment. Textured HDPE shall not be dragged across the subgrade/RCC AND UCB surface.

5.2.3 GEOTEXTILES

5.2.3.1 DEFINITIONS

Geotextile: A planar, permeable, polymeric (synthetic or natural) textile material, which may be non-woven, knitted or woven, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications.

Minimum Average Roll Value (MARV): For geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97% confidence that the property in question will meet published values. For normally distributed data, "MARV" is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

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.

5.2.3.2 REFERENCES

The PA specification includes references to specifications and test procedures of:

- the American Society for Testing and Materials (ASTM);
- Geosynthetic Research Institute (GRI) Test Methods and standards;
- All other specifications contained, or referred to, in this Document.

5.2.3.3 MANUFACTURING, TRANSPORT AND STORAGE

5.2.3.3.1 WORKMANSHIP AND APPEARANCE

The finished geotextile shall have good appearance qualities. It shall be free from such defects that would affect the specific properties of the geotextile, or its proper functioning.

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

5.2.3.3.2 MQC SAMPLING, TESTING, AND ACCEPTANCE

Geotextiles shall be subject to sampling and testing to verify conformance with this specification. Sampling shall be in accordance with the most current modification of ASTM Standard D 4354, using the section titled, "Procedure for Sampling for Purchaser's Specification Conformance Testing." In the absence of purchaser's testing, verification may be based on manufacturer's certifications as a result of testing by the manufacturer of quality assurance samples obtained using the procedure for Sampling for Manufacturer's Quality Assurance (MQA) Testing. A lot size shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

Conformance testing to be done and approved during manufacturing and also on arrival on site.

5.2.3.3.3 MQC RETEST AND REJECTION

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.

5.2.3.3.4 SHIPMENT AND STORAGE

Geotextile labelling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style, and roll number. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

Each geotextile roll shall be wrapped with a material that will protect the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 70°C, and any other environmental condition that may damage the property values of the geotextile.

5.2.3.3.5 CERTIFICATION

The contractor shall provide to the Construction Manager a certificate stating the name of the manufacturer, product name, style number, chemical composition of the filaments or yarns, and other pertinent information to fully describe the geotextile.

The manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

The manufacturer's certificate shall state that the finished geotextile meets MARV requirements of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.

Either mislabelling or misrepresentation of materials shall be reason to reject those geotextile products.

5.2.3.4 MATERIAL SPECIFICATION FOR GEOTEXTILES

Three types of geotextiles have been specified for use in the works, namely:

- Type A Separation geotextiles, and
- Type B Protection geotextiles,

Where products are tested under other test methods not specified, the methods and results should accompany the tender. The Construction Manager retains the right to reject a test method and instruct the Tenderer to have the product tested under the specified tests.

All geotextiles must be stable in the presence of the chemicals typically found at Lafarge PCDs and should be resistant to attack from these chemicals. Typical characteristics of the leachate can be found in the design report. This information is only representative of the leachate that would be in contact with the lining system. All geotextiles should be stable at a temperature of 100 °C.

All geosynthetics must be stable in the presence of the chemicals typically found in a Pollution control dam and should be resistant to attack from these chemicals.

5.2.3.4.1 TYPE A GEOTEXTILE: SEPERATION GEOTEXTILE

The **Type A** geotextile shall be a non-woven geotextile used for separating drainage aggregates and sand from the surrounding materials and preventing the drainage medium from becoming fouled. The geotextile must be a non-woven continuous filament needle punched polyester (PET) geotextile that meets the requirements of a **Class 2** (moderate survivability) geotextile as per GRI-GT13. The geotextile must comply with the following material specifications tabulated below (in line with the GRI-GT13(a) (Table 2(b), page 7 of 9 of Rev 4):

Table 9: Type A Geotextile Manufacturer QA/QC Requirements

Property 3	Units	Value Elong. < 50%	Value Elong. ≥ 50%	Test method
Grab Tensile Strength	N	1100	700	ASTM D4632
Trapezoidal tear strength	N	400	250	ASTM D4533
CBR Puncture strength	N	2250	1400	ASTM D6241
Permisivity	Sec-1	0.02	0.02	ASTM D4491
Apparent Opening Size	mm	0.60	0.60	ASTM D4751
Ultraviolet Stability	% Ret @ 500 hrs	50	50	ASTM D7238

*Note equivalent ISO test methods listed in GRI-GT12b, can be used interchangeably and all values are based on MARV results.

5.2.3.4.2 TYPE B GEOTEXTILE: PROTECTION GEOTEXTILE

The **Type B** geotextile shall be a non-woven geotextile used for protection or cushioning layer, protecting the geomembrane to long-term traffic that may access the PCD once operational. The geotextile must be a non-woven continuous filament needle punched polyester (PET) geotextile manufactured with a mass per m² of at least 600 g/m². The geotextile must comply with the following material specifications tabulated below (in line with the GRI-GT12a (Table 1 (b), page 6 of 7 of Rev 2):

Table 10: Type B Geotextile Manufacturer QA/QC Requirements

Property 3	Units	Value	Test method
Min. mass per m ²	g/cm ²	600	SANS 1525
Grab Tensile Strength (weakest direction)	kN	50	ASTM D4632
Trapezoidal tear strength (weakest direction)	N	640	ASTM D4533
CBR Puncture strength	kN	4.1	SANS 12236
Tensile strength (weakest direction)	kN/m	27	SANS 1525
Interface Friction with Underlying Geomembrane	°	8 (Residual)	ASTM 6243
Interface Friction with Overlying Soilcrete Protection Layer	°	20(Residual)	ASTM 6243
All values are MARV			

5.2.4 GEOSYNTHETIC CLAY LINER

5.2.4.1 SCOPE AND INTRODUCTION

This specification covers the requirements for furnishing materials, equipment, and services necessary and incidentals to supply and install reinforced geosynthetic clay liners (GCLs). GCLs are also termed Clay Geosynthetic Barriers (CGBs). In this contract document the term "GCL" shall be used in abbreviation of the word Geosynthetic Clay Liner.

In this project the GCLs are to be placed in the basal lining layer works construction.

5.2.4.2 INTERPRETATIONS

5.2.4.2.1 SUPPORTING SPECIFICATIONS

The publication "GRI-GCL3: Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)" shall form part of this specification. This publication shall, unless otherwise stated, be the edition in effect 30 (thirty) days prior to the date of issue of this Contract for tender purposes. Any contradictions between publication/s and this Contract shall be submitted to the Construction Manager for decision.

The sections pertaining to a **needle punched GCL in the GRI-GCL3 specification** are adopted and accepted by this standard as the manufacturing quality control specification.

GRI Standards are constantly being updated by the Geosynthetic Research Institute (GRI) and many of the documents are freely available online at website address: **www.geosynthetic-institute.org/specs.htm**.

EN-ISO or any other standard which can be shown to be equivalent to the standards specified may be acceptable.

5.2.4.2.2 UNITS

The values stated in SI (metric) units are to be regarded as the standard.

5.2.4.2.3 SAFETY

This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

5.2.4.2.4 DEFINITIONS RELATING TO GEOSYNTHETIC CLAY LINERS

For the purposes of this specification, the following definitions shall apply:

Bentonite: a distinct type of fine-grained clay soil typically containing not less than 80% Montmorillonite clay, usually characterized by high swelling upon wetting. For this project the type of Montmorillonite mineral is a Sodium (Na) Montmorillonite mineral. The type of Montmorillonite is a naturally occurring Sodium (Na) Montmorillonite mineral. No activated Sodium (Na) Montmorillonite minerals will be acceptable. The Bentonite must be similar to "Wyoming"-type Bentonite or equivalent. The Bentonite must be rich in Smectites and dominated by Smectites and Montmorillonite.

Carrier Layer: The material that forms the base layer of a needle punched GCL. This consists of

a nonwoven or woven geotextile, or a combination of these.

Contractor: The main contractor who is responsible for the construction of the works.

Cover Layer: The material that forms the top layer of a needle punched GCL. This consists of a non-woven geotextile.

Geofilm: a thin polymeric film which is essentially impermeable.

Geosynthetic: A planar, polymeric (synthetic or natural) material used in conjunction with soil/rock and/or any other geotechnical material in civil engineering applications.

Geosynthetic Clay Liner (also known as Clay Geosynthetic Barriers): An assembled structure of geosynthetic materials and low hydraulic conductivity earth materials (clay or bentonite), in the form of a manufactured sheet, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications.

Geotextile, non-woven: A geotextile in the form of a manufactured sheet or web of directionally or randomly orientated fibres, filaments or other elements, mechanically and/or thermally and/or chemically bonded.

Geotextile, woven: A geotextile produced by interlacing, usually at right angles, two or more sets of yarns, fibres, filaments, tapes or other elements.

GRI-GCL3: The listed "GRI" specification for GCLs on the [3](#) website or any website replacing this address (managed by GRI).

Lining Contractor: A specialist sub-contractor to the main contractor who is responsible for the installation of a geomembrane liner on behalf of the main contractor.

Normal temperature: A temperature between 15°C and 32°C.

Reinforced GCL: A GCL in which the carrier and cover layers are mechanically linked through the bentonite component to provide internal shear strength to the GCL.

Wrinkle, wave or fold: Undulation in the liner that is caused by installation methods, temperature fluctuations or activities like cover placement taking place on the liner.

5.2.4.2.5 DEFINITIONS RELATING TO QUALITY PROGRAMMES

This CQA Plan is devoted to Construction Quality Assurance. Both quality assurance and quality control in a construction project are aimed at ensuring quality of the final product - the infrastructure. However, Quality Assurance and Quality Control are distinctly different activities. Refer to the GRI-GCL3 specification for definitions relating to quality programmes. The definitions listed below provide a brief overview of the applicable quality programmes for reference:

Manufacturing Quality Control (MQC): The GCL shall conform to the requirements as stated in GRI-GCL3 for GT-Related reinforced GCL.

Construction Quality Control (CQC): Monitors work as it happens and is a planned system of inspections that is used to directly monitor and control the quality of a construction project. Construction Quality Control shall be performed by the Lining Contractor or for natural soil materials by the Earthworks Contractor and is necessary to achieve quality in the constructed or installed system. Construction Quality Control refers to measures taken by the installer or Contractor to determine compliance with the requirements for materials and workmanship as stated in the Drawings and Project Specifications.

Construction Quality Assurance (CQA): A planned system of activities that provides the Employer, Construction Manager and Permitting Authorities assurance that the facility was constructed as specified in the design. Construction Quality Assurance includes inspections, verifications, audits and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. Construction Quality Assurance refers to measures taken by the Construction Manager to assess if the Lining Contractor is in compliance with the Drawings and Project Specifications. A third party CQA inspector may be appointed by the Employer to oversee the lining installation.

5.2.4.3 MATERIALS AND MANUFACTURING OF GCLS

5.2.4.3.1 QUALIFICATION OF GCL MANUFACTURER

The GCL material to be supplied and installed for this Contract **shall be GRI-GCL3 (Reinforced GCL GT related) GCL. The carrier layer shall be a woven geotextile only.**

Details of the Manufacturer(s) shall be provided in the Schedules forming part of this Tender.

The Manufacturer(s) shall be able to provide sufficient production capacity and qualified personnel to meet the demands of the project.

For this purpose, the following information regarding the Manufacturer(s), as a minimum, **must be completed/ submitted in Returnable Schedule** with the Tender):

1. Corporate background and information (to be completed on the returnable Schedule) and declare ISO 9002: 1994 or ISO 9001:2000 certification (to be attached to the returnable Schedule)
2. Manufacturing capabilities:
 - Information on plant size, equipment, number of shifts per day, and production per shift (to be completed on the returnable Schedule);
 - List of materials used, material properties, including certified test results and further details of completed projects (to be supplied if requested by the Employer).
3. Completed Projects: provide details of completed projects for which the Manufacturer has produced the same geosynthetic clay liners with **a minimum total area of 500,000 m² being manufactured.** (This requirement is for GCL similar to that specified above)

4.

It is required that the manufacturers of the geosynthetic membranes have ISO 9002: 1994 or ISO 9001:2000 certification (even though more recent certifications are available). The Tenderer is to state in the returnable Schedule whether the manufacturer is ISO 9002:1994 or ISO 9001:2000 certified.

5.2.4.3.2 GCL PLANT AUDIT

SCOPE

The Construction Manager or a representative of the Construction Manager may perform an audit of the manufacturing and quality control procedures used by the Manufacturer,

specifically for the production of the GCLs to be used for installation at the Employer's facility.

QUALITY CONTROL

The manufacturer shall make available to the Employer and Construction Manager, Manufacturing Quality Control (MQC) manuals, which outline all quality procedures, to be implemented for the manufacture of the GCLs.

The Manufacturer shall provide certification for laboratory testing equipment. The Construction Manager may verify that, during select runs of material, all MQC procedures are performed.

MANUFACTURING PROCESS

In general, the Manufacturer shall provide access for the Construction Manager to all equipment used to manufacture the GCLs. This does not include divulging trade secrets, formulations and procedures that are not commonly known as basic manufacturing processes.

The Construction Manager shall be furnished with the relevant test results, in accordance with this specification, and the QC certificates

5.2.4.3.3 MANUFACTURING OF GEOSYNTHETIC CLAY LINER (GCL)

MANUFACTURING AND MATERIALS

Refer to the GRI-GCL3 specification for the manufacturing quality control requirements of GRI-GCL3 (Reinforced GCL GT related) GCLs.

The Construction Manager shall be informed and give approval if the source of bentonite is changed from the originally offered GCL product.

QUALITY CONTROL SUBMISSIONS

Manufacturing Quality Control documentation from the manufacturer of each type of GCL to be supplied must be submitted for approval to the Construction Manager. Submittals must be made before the materials are purchased and delivered to site. Submittals to include:

- Dates of manufacture
- Bentonite and geotextile supplier,
- Batch numbers and roll numbers, length and width
- Documentation of the manufacturer's specific quality control program, which shall provide test data indicating the actual test values per roll or per batch, as may be applicable as called for in GRI-GCL3.

MATERIAL SPECIFICATIONS

The quantities set out in the schedule of quantities have been determined from data available at the time. However, the liability shall rest entirely and solely with the Lining Contractor to determine before ordering, the required types and quantities of the various materials required for the completion of the Works in accordance with the specifications and the drawings issued to the Lining Contractor for construction purposes

Any reliance placed by the Lining Contractor on the estimated quantities stated in the Schedule of Quantities, or measurements made by the Lining Contractor from the drawings

shall be entirely at the Lining Contractors risk and the Employer accepts no liability whatever in respect of materials ordered by the Lining Contractor on this basis.

All geosynthetic areas stated in the bill of quantities are net.

GEOSYNTHETIC CLAY LINER (GCL)

The GCL material to be supplied and installed for this Contract **shall conform to the requirements as stated in GRI-GCL3 (Reinforced GCL GT related) GCL. The carrier layer shall be a woven geotextile only.**

Replace the corresponding parameter in Table 1(a) of GRI-GCL3 with:

Parameter	ASTM Test Method	Value	MQ Test Frequency
Bentonite	D 5993	4000 g/m ²	2 000 m ²

Add the corresponding parameter in Table 1(a) of GRI-GCL3 with:

Parameter	ASTM Test Method	Value	MQ Test Frequency
Hydrated Internal Shear Strength (min) at a normal load of 30 KPa	D6243	24 kPa	2 000 m ²

Bentonite Type: All GCLs shall contain natural sodium bentonite unless otherwise specified on the drawings or in the Project Specifications.

The GCL Product being offered must be suitable for the application as indicated on the drawings.

In addition, a minimum Interface Friction Angle between GCL & Underlying Material Layer of ≥15° using ASTM D5321 will be required.

TESTING

All MQC and CQC testing and reporting thereon are described in the supporting specifications.

In addition to the above, the following independent 3rd party test will be carried out. For each type of GCL one set of tests will be carried out. A set of tests will consist of conformance to the properties listed in Table 14 below:

Table 11: GCL Manufacturer QA/QC Requirements

Property	Test Method
Clay mass per unit area	ASTM D 5993
Swell Index	ASTM D 5890
Fluid Loss	ASTM D 5891
Hydraulic Conductivity	ASTM D 5887
Strip Tensile Strength	ASTM D 6768
Shear strength	ASTM D 6243

The testing procedure is as follows:

- I. One set of six 400mm x 400mm samples are to be cut evenly spaced across the width of the roll in the presence of the Construction Manager or his Representative.
- II. The samples must be cleaned and packaged and sent to a laboratory as specified by the Construction Manager. Alternative testing facilities will be considered, if the supplier can provide proof of such a testing facility's independence and competence.
- III. Information on the specific roll numbers from which the samples are cut are to be provided to the Construction Manager, as well as confirmation of dates on which samples have been sent and arrival at the testing facility.
- IV. The Construction Manager may require the testing to be repeated once the material is delivered to site.

5.2.4.4 PACKAGING, TRANSPORTATION, HANDLING AND STORAGE

The products shall be packaged, transported, unloaded and stored in accordance with the manufacturer's instructions, subject to the Construction Manager 's approval, and generally in accordance with ASTM Standard D 5888, "Standard Guide for Storage and Handling of Geosynthetic Clay Liners".

5.2.4.4.1 PACKAGING AND IDENTIFICATION

All GCL rolls shall be packaged in opaque moisture and ultraviolet resistant plastic sleeves. The roll cores shall be sufficiently strong to resist collapse during transit and handling. The Construction Manager has the right to reject any roll if the core has collapsed or if the roll is damaged in any other way.

Before shipment, the manufacturer shall label each roll, both on the surface of the plastic protective sleeve and on the inside of the core. Labels shall be resistant to fading and moisture degradation to ensure legibility at the time of installation. As a minimum the roll labels shall identify the following:

- I. Product name, grade and manufacturer

- II. Length and width of roll
- III. Gross mass of roll
- IV. Production lot/batch number and individual roll number
- V. Manufacturers quality approval label
- VI. Label with handling guidelines

5.2.4.4.2 AUXILIARY PRODUCTS

Any accessory bentonite used for sealing seams, penetrations, or repairs, shall be high-quality powdered or granular sodium bentonite from a recognized producer and must comply with the same specifications as the GCL itself, as contained in GRI-GCL3.

5.2.4.4.3 TRANSPORTATION

If slings are used to load or off load and transport GCL rolls, an appropriate core pipe must be used to support the weight of the roll. During transportation, a roll may not deflect by more than half its diameter.

5.2.4.4.4 HANDLING OF MATERIALS

The method of unloading and handling of GCL rolls shall be as specified below. Any deviation from these procedures shall be pre-approved by the Construction Manager in writing.

GCLs must be supported during handling to ensure worker safety and to prevent damage to the product. Stacking should always allow easy access to at least one end of each roll for handling equipment as well as for roll identification. The construction quality assurance officer shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the liner material itself.

Under no circumstances may the rolls be dragged, lifted from one end, lifted in the middle of the roll, lifted with only the forks of a forklift, or dropped to the ground from the delivery vehicle.

Spreader Bar Assembly: A spreader bar assembly shall include a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the GCL core while the spreader bar beam will prevent chains or straps from chafing the roll edges. Lifting the rolls should be done with a sufficiently strong pipe/bar that can easily fit in the roll core. This can be accomplished with a 63mm to 75mm outside diameter steel pipe/bar, with a wall thickness capable of providing sufficient beam strength to support the weight of the roll without bending, which, depending on the GCL type, can be up to 1200kg or more.

Carpet Spike (or "stinger"): A carpet spike is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment and the other end rounded off to allow easy insertion into roll material cores. If a carpet spike is used, it must be at least $\frac{3}{4}$ the width of the roll and inserted to its full length into the roll core to prevent excessive bending of the roll when lifted.

Roller Cradles: Roller cradles consist of two rollers, which both support the GCL roll and allow it to unroll freely without significant deflection.

A method statement shall be submitted to the Construction Manager by the Contractor before ANY GCL material is off-loaded on site.

5.2.4.4.5 INSPECTION UPON DELIVERY

Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Possible product conditions and actions are listed below:

- I. Rolls, including the roll cores, exhibiting damage shall be marked and set aside for closer examination during installation. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape before being placed in storage to prevent moisture damage.
- II. The presence of free-flowing water (more than small amount of condensate from bentonite itself) within any roll packaging shall require that the roll be set aside for further examination to ascertain the extent of any damage.
- III. GCL rolls delivered to the project site shall be those indicated on GCL manufacturing quality control certificates.
- IV. Repairs to damaged GCL rolls shall be performed in accordance with the repair method detailed in this this specification, during installation, if approved by QCAO and/or engineer.

All material deliveries shall be logged and a summary of this log presented to the Construction Manager no more than three (3) days after delivery to site for any particular material type.

The Construction Manager or his representative should be present, whenever possible, to observe the material delivery and unloading on Site. The Construction Manager reserves the right to reject any roll at any stage prior to installation should it exhibit any of the above damages or non-conformance.

5.2.4.4.6 STORAGE

Storage of the GCL rolls shall be the guidance of the Installer party. All GCL rolls shall be stockpiled and maintained dry in a well-drained flat area away from high-traffic areas but sufficiently close to the active work area to minimize handling. Rolls should be stacked off the ground using wooden pallets. The top of the wooden pallets shall be at least 100mm above natural (surrounding) ground level.

The area where the material is to be stored shall be free of any protrusions, rocks and other sharp objects, which could damage the material. The Main Contractor will clear an area of sufficient size for the storage of materials within 1km of the construction site next to the Main Contractor's campsite.

Rolls shall not be stacked on uneven or discontinuous surfaces, in order to prevent bending, deformation, product thinning and damage to the GCL or cause difficulty during handling.

GCL roll stacks shall be limited to the height at which installation personnel can safely manoeuvre the handling apparatus, to a maximum height of three rolls. Stacks or tiers of rolls must be situated in a manner that prevents sliding or rolling by chocking the bottom layer of the rolls.

An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for GCL material stored outdoors.

Bagged bentonite material shall be stored in a dry location free from the influences of weather conditions. Bags shall be stored on dry surfaces that will prevent pre-hydration.

5.2.4.5 CONSTRUCTION

5.2.4.5.1 CONSTRUCTION QUALITY CONTROL

CONSTRUCTION QUALITY CONTROL (CQC) PLAN

The CQC Plan shall be submitted to the Construction Manager at least 5 days before construction commences. It shall include:

- I. A site staff organogram indicating authority and responsibilities
- II. Proposed panel layout drawing(s)
- III. A Method Statement detailing the Contractor's proposed construction procedure of the specific elements of the GCL installation including activities preceding and following the installation (i.e. surface preparation and cover placement). No work related to such elements shall commence before the method statement has been submitted and agreed upon.
- IV. A delivery note checklist template
- V. Acceptance and non-conformance templates for subgrade, panel placement, seaming and repairs.
- VI. All necessary Construction Quality Control forms for completing during the installation of the GCLs.

QUALIFICATION OF THE GCL CONTRACTOR

The GCL shall be installed by a competent Contractor. If the Contractor has no prior experience installing GCLs, adequate training should be provided by the GCL supplier to the satisfaction of the Construction Manager. The cost of the training shall be taken into account in the payment items.

NOTIFICATION OF CHANGES

After acceptance of the CQC Plan, the Contractor shall notify the Construction Manager in writing prior to any proposed change. Proposed changes are subject to acceptance by the Construction Manager.

CONSTRUCTION QUALITY ASSURANCE

Duties of Construction Manager 's Construction Quality Assurance Personnel

The personnel of the Construction Manager include:

- 17 The CQA Officer, who may be the same person as the Construction Manager 's representative;
- 18 The Construction Manager 's representative who is located at the site; and
- 19 Any other staff or assistant who may be used on the site.

The general duties of a qualified and experienced CQA Officer are set out below. The CQA Officer shall review all site-specific documentation, proposed panel layouts, Contractor's GCL construction programme and methods, and the Contractor's CQC Plan and he shall attend the Site Meetings where necessary and may be required to produce a final report.

INSTALLATION

General

The GCL shall generally be installed as per ASTM D 6102, except where otherwise indicated in the following sections of this specification. The CQAO shall verify that the subgrade is suitable for supporting the geosynthetics, any underlying layers are clean and free of deleterious materials prior to deployment, and that anchoring is achieved as specified. The CQAO shall observe and document that all geocomposite materials are covered with the approved material and that traffic or hauling equipment does not damage the material during installation, regardless of CQAO observing the Works, the onus rests with the Contractor to undertake the installation in such a way as to avoid damage to the materials.

Temporary Anchoring

The Contractor shall supply double lined sandbags or other method approved by the Construction Manager to keep all material in place during the installation process. The bags are to be filled with sand.

Panel Layout

Prior to commencing GCL installation the Contractor shall prepare and submit to the Construction Manager for approval a proposed panel layout drawing, drawn to scale, showing the proposed deployment pattern and sequence. The location of overlaps and details thereof must also be shown. No deployment of GCL shall commence until the Construction Manager has approved the panel layout. This deployment plan may be requested by the Construction Manager at the tender stage.

In preparing the panel layout, the Contractor shall take into account the construction schedule, access restrictions and the following limitations placed on seam locations:

- I. To the maximum extent possible, overlaps shall be parallel to the slope (down the slope).
- II. The number of transverse seams (perpendicular to slope) on slopes shall be minimized. Where such seams are unavoidable, the details of these seams must be approved by the Construction Manager.
- III. Seams at inside and outside corners, odd-shaped geometric configurations, seam convergences, and small panels shall be avoided if possible.

Each panel and penetration shall be given a simple and logical identification code consistent with the panel layout drawing. The panel identification should include the panel batch and roll number. The panel layout drawing shall be updated from time to time to reflect the actual deployment configuration.

On completion of the installation, the Contractor shall prepare and submit to the Construction Manager as-built drawings to scale showing the final panel layout.

Anchor Trench

In some cases, the GCL can be anchored in the same trench as any adjacent geosynthetic liner components (if used). Dimensions and location of the trench are provided on the project drawing/s. The front edge of the trench is to be rounded, so as to prevent stress concentrations on the GCL. Care should be taken to preserve the integrity of the sides of the trench during GCL installation.

The backfill of the anchor trenches must only commence after the Construction Manager has inspected and accepted the trench for backfill. The Construction Manager requires the trench only to be backfilled after the protection geotextile layer has been installed.

The backfilling of the trenched shall be done in accordance with SANS1200DB, with particular reference to SANS1200 DB, Clause 5.7.1.

The GCL must be installed in the trench as detailed on the project drawings.

Deployment

Prior to deployment, the CQAO shall verify that the subgrade or synthetic liner is suitable for supporting the geosynthetics, any underlying layers are clean and free of deleterious materials prior to deployment, and that anchoring is achieved as specified.

The GCL shall be installed on the approved areas shown on the drawings, or as directed by the Construction Manager, using methods and procedures that ensure a minimum of handling. The orientation of the GCL, i.e. which side faces up, shall be in accordance with the drawings, or as instructed by the Construction Manager.

When possible, GCL deployment should begin at the higher elevations and proceed to the lower elevations. At no time shall GCL rolls be released and allowed to unroll freely under gravity. Damaged, faulty or suspect areas shall be marked for repair. The method used to unroll the GCL shall not damage any underlying geosynthetics or allow stones, mud, or debris to be trapped under the GCL. Care shall be taken to prevent damage to the either surface of the GCL when it is finally positioned across the subgrade or underlying geosynthetic.

The GCL shall be placed one panel at a time in a relaxed condition with the required overlap so that it is in intimate contact with the underlying surface at all locations and free of tension or stress upon completion of the installation. All necessary precautions, including installing extra material, shall be taken to avoid bridging of the material. Cutting and trimming of GCL placed over geomembranes shall be undertaken with hooked-blade knives or another approved cutter. Special care shall be taken to protect other geosynthetic materials from damage that could be caused when cutting.

It is important to ensure that the GCL is not left exposed to the elements and therefore the subsequent covering activities must be co-ordinated accordingly with the GCL installation.

The Contractor shall only deploy as much GCL that can be covered in a reasonably short time in the event of precipitation or as can be covered by the end of the working day with geomembrane, or temporary plastic sheeting.

The layout and sequence of panel placement is determined by the direction of water run-off. Panels are laid out according to previously approved panel layout drawings. Generally, the installation is started at the up-wind side and at the highest elevation so that any rainfall runs off the lower part of the impoundment, preventing pooled water from hydrating the GCL.

If unplanned premature hydration occurs the Construction Manager shall be notified. If the extent of the premature hydration is such that, when an average weight person walking over the GCL causes "toothpasting" to occur, the hydrated GCL may need to be replaced at the discretion of the Construction Manager.

The extent of the damage of the prematurely hydrated GCL section can be assessed taking the following into account:

- I. Separation and damage of the geotextiles
- II. Depth of indentations (and corresponding bentonite thinning) where it has been walked or driven on.
- III. The integrity of the overlaps and other bentonite enhanced seams.

A sharp utility knife should be used for cutting the GCL if required, e.g. around penetrations. Frequent blade changes are recommended to avoid damage to the geosynthetic components of the GCL during the cutting process. Removed blades should not be

discarded on or under the installed GCL. Cutting should be done on an adequately sized, preferably wooden, cutting board.

The GCL may not be unrolled elsewhere or re-handled after it is unrolled.

Deployment on flat areas shall be conducted in the same manner as that for the slopes; however, care should be taken to minimise "dragging" the GCL. A slip-sheet may be used to facilitate positioning of the liner while ensuring the GCL is not damaged by underlying harsh surfaces.

The contractor shall only install as much GCL as can be covered at the end of each working day by the HDPE and/or sand cover layers. Only those GCL panels, which can be anchored and covered in the same day, shall be unpacked and installed. If exposed GCL cannot be permanently covered before the end of a working day, it shall be temporarily covered with plastic or other waterproof material to prevent hydration. No GCL shall be left exposed overnight. Exposed edges of the GCL shall be covered by temporary water-resistant sheeting until work commences again.

Bentonite paste of similar grade to the actual GCL should be placed between panels at a minimum rate of 900 grams per linear meter of seam.

The overlap zone shall be kept clean from any foreign material.

No overlaps shall be placed in low points or in drain cavities and shall be kept 1m away from the toe of all slopes.

Overlaps shall be to the Construction Manager 's requirements and shingled in the direction of anticipated water flow.

Seaming

General

GCL seams shall be used where called for on the Drawings, shown on the approved panel layout, or as directed by the Construction Manager. The seam shall be created by overlapping adjacent edges and enhancing the seam as recommended by the manufacturer, or as instructed by the Construction Manager.

The overlap zone shall be kept clean and shall not be contaminated with loose soil or other debris. There shall be no folds in the overlap zone and no traffic or walking shall occur on the completed seam. No end overlaps shall be positioned in sumps or inverts.

Overlap

Overlaps shall be 500mm minimum horizontally and vertically and shingled in the direction of anticipated water flow.

If the GCL does not incorporate a mechanism to ensure longitudinal overlap sealing overlap areas will require on site overlap bentonite sealing. Edges are pulled back and bentonite of the same source to that used in the product should be poured/smearred continuously along all seam edges. The amount of bentonite must be sufficient to create a thin-paste layer over the entire overlap area.

Horizontal seams on steep slopes (steeper than 1V:6H) should be avoided. However, these may be required for long slopes, in which case the horizontal seams shall be constructed as directed by the Construction Manager.

When the GCL is cut to fit into small areas, in corners or around structures adjacent panels should be overlapped a minimum 500mm or as directed by the Construction Manager, adding

abundant bentonite in overlapped areas, if the overlapped area does not cover a bentonite enhanced longitudinal edge.

REPAIRS

General

Any portion of the GCL or seam showing a defect shall be repaired. Reasons for requiring repairs to the GCL installation include, but are not limited to:

- I. A hole, cut, or tear
- II. Insufficient overlap
- III. Bridging
- IV. GCL material defects
- V. A hard object underneath the GCL
- VI. Unconfined and unhydrated GCL material exposure to harmful liquids during installation. This could include hydrocarbon fuels, chemicals, pesticides, or non-compatible leachate, as determined by the Construction Manager.
- VII. Premature hydration

Repair Methods

Agreement on the appropriate repair method shall be reached between the Contractor and the Construction Manager. Repairs shall be undertaken using one or a combination of the following methods:

Patching

Patching shall be used to repair holes, cuts or tears, insufficient overlap, bridging, GCL material defects, and to remove hard objects underneath the GCL. Patching shall comprise installing a new piece of GCL of the same material type and thickness extending at least 500 mm beyond the affected area in each direction. This 500 mm area must be augmented with bentonite powder/granules to the supplier's normal jointing requirements for patches and to the Construction Manager's approval. Patch seams shall be created as described in PGCL 5.3.5.

Patches on slopes steeper than 1V:6H shall be minimized, and in this case the Construction Manager shall approve the location and size of such a patch. In addition to bentonite augmentation around the edge of patches on slopes steeper than 1V:6H the patch shall be temporarily secured such that it is not displaced during cover placement. Patches may be tucked under the damaged area to limit patch movement.

No patches shall overlap. If this is required to make a repair, the entire area, including all previous patches in the near vicinity, shall be covered with a single large patch. The Construction Manager shall approve deviations from this requirement.

All patches on the GCL should be recorded by a GPS global positioning system as positions stored and given to the quality control officer/ Construction Manager and indicated on the As-Built Panel layout.

SEALING AROUND PENETRATIONS AND STRUCTURES

The GCL shall be sealed around penetrations and structures embedded in the sub-grade.

Bentonite powder/granules shall be used liberally to seal the GCL to these structures in accordance with the drawings. An example detail is shown in Figure 1 below.

When the GCL is placed over an earthen subgrade, a “notch” should be excavated into the sub-grade around the penetration. The notch should then be filled with bentonite or bentonite paste. A secondary collar of GCL should be placed round the penetration with a minimum overlap of 500mm.

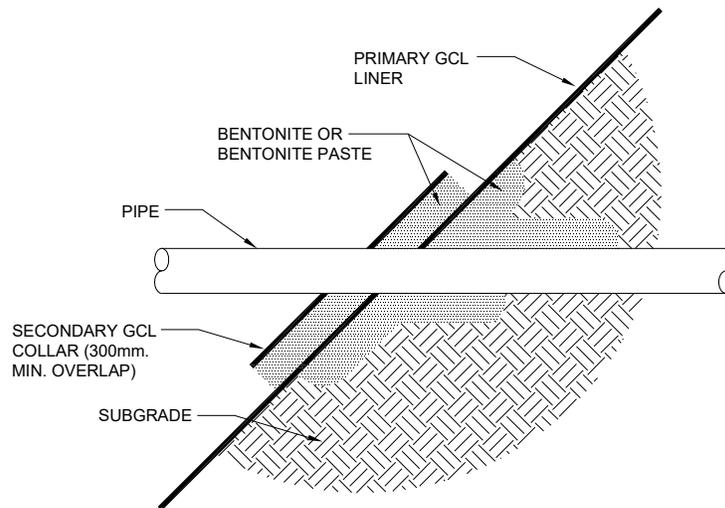


Figure 1: Typical pipe penetration section detail (after ASTM D 6102) (Note: change min overlap to 500mm)

HYDRATION

Prior to the installation of the GCL and after the surface has been accepted and signed off for GCL installation by the CQAO, the surface of the bulk formation layer shall be watered to at least OMC +2% prior to deploying the GCL. No prehydration of the GCL will be allowed unless specifically called for in the project specifications or on the drawings.

COVER PLACEMENT

GEOMEMBRANE LINER

Once the GCL is hydrated, it will be immediately covered with the geomembrane liner as per the placement requirements dictated in this document. Only the amount of GCL that can be covered with HDPE Liner will be deployed on a certain working day. Under no circumstances is a hydrated GCL to be installed without covering it with HDPE Liner (including welding of joints) and left overnight.

Any exposed GCL edges shall be covered with temporary plastic sheeting that is anchored under the leading edge of the soil cover and folded at least 300 mm under the leading edge of the GCL. The protected end of the GCL shall be held in place with temporary ballast until installation resumes.

PROTECTION LAYER

It is a requirement of the design that a 250 mm thick soilcrete protection layer be installed within a period of 14 days from the day on which the GCL is placed. The soilcrete is to be placed within an approved geocell and will both protect the geomembrane and provide the necessary minimum confining pressure to the GCL to avoid GCL panel shrinkage and moisture

losses.

No vehicles should be allowed to traffic the area directly above the GCL unless at least 300mm soil separation exists (or the 250 mm protection layer has been installed and approved) between the GCL and the vehicle to adequately distribute the vehicle load for a short period of time of pass-over.

5.2.4.6 TOLERANCES

Manufacturing tolerances to be in accordance with GRI-GCL3 and any associated standards.

The maximum permissible deviations for overlaps in joints, patches and seams shall be 10% of the specified overlap.

Verification of Permissible Deviations:

- Dimensions will be verified at normal temperature; measurements being made with a tape at normal temperature.
- For installation, at sunrise or at such time as when, in the opinion of the Construction Manager, the effect of the sun is of no consequence.
- All PDs will be rounded up to the next whole millimetre

Table 12: GCL Installation Tolerances

ITEM	PERMISSIBLE DEVIATION		
	DEGREE OF ACCURACY		
	III	II	I
Substrate			
Flatness of substrate		Note 1	
Flatness of GCL		Note 2	
Anchor trenches			
Anchor trench Position on plan	*	+/-75mm	*
Anchor trench dimensions	*	-0mm	*
Anchor trench surface irregularities in contact with GCL	*	50mm	*
GCLs			
Refer GRI GCL3 for MQC			
Waves & Folds		None	

Note 1: Substrate flatness

The top layer of the subgrade layer shall be graded and compacted using a smooth drum roller where it needs to be prepared for the placing of the geomembrane and shall be finished such that no gap greater than 30mm can be measured beneath a 3m straight edge. The surface shall be clear of loose stones and may not have protrusions (of any sort) in excess of 5

mm of the final layer ready to accept the GCL. No abrupt changes in falls or alignments will be allowed.

Note 2: Liner flatness

The liner will be laid flat on the surface without any fold or wrinkles.

5.2.4.7 TESTING

5.2.4.7.1 GENERAL

The GCL material shall be tested for compliance with the specifications listed in Table 1 (a) in GRI-GCL3 (Reinforced GCL GT related) by the test methods and frequencies indicated. Sampling of GCL is to be in accordance with ASTM D6072.

Immediately upon manufacture, Conformance Testing may, at the discretion of the Construction Manager, be carried out by an independent accredited laboratory (MQA laboratory). Common important conformance tests are listed in Table 1. Further tests, such as GCL shear strength (ASTM D 6243), may be required by the Construction Manager for specific projects. The testing frequency shall be at the discretion of the Construction Manager, but the frequency shown in Table 1 (a) in GRI-GCL3 (Reinforced GCL GT related) can be used as a guideline. The Construction Manager shall approve the laboratory before any testing is done. The Construction Manager has the right to reject any roll or production batch if the samples do not pass conformance testing.

The Contractor shall supply with his tender, a Construction Quality Control Plan which clearly indicates documentation ensuring compliance with the necessary material specifications, and control points requiring quality control checking during construction/installation.

The Construction Manager/CQAO may request test results produced by a certified laboratory independent of the manufacturer to verify the claimed properties, prior to approval of the product(s) offered. All MQC and CQC testing and reporting thereon are described in the GRI-GCL3 specification.

5.2.4.8 DOCUMENTATION

5.2.4.8.1 GENERAL

An effective construction quality assurance plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibility for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Construction Manager/CQAO will ensure that all quality assurance requirements have been addressed and satisfied.

5.2.4.8.2 PRIOR TO INSTALLATION

The Installer/Contractor is to provide the following to the Construction Manager/CQAO before installation on site:

- I. Manufacturers conformance certificates
- II. A drawing indicating the position and numbers of each individual panel that will be installed (Panel layout)
- III. A Method Statement describing the method of installation and quality control documentation to be completed

- IV. A Project Quality Plan with organization chart and detailing inspection procedures

5.2.4.8.3 DURING INSTALLATION

The Installer/Contractor is to complete the following:

- I. Material receipt with roll numbers
- II. Subgrade surface acceptance documentation
- III. Panel layout – Panels installed and repair positions
- IV. Panel Placement Form showing the location of all panels and joints
- V. Project Quality Plan – Signatures
- VI. Certificate of Acceptance

The Construction Manager's representative is to complete the following daily reports:

- I. Field notes, including memoranda of meetings and/or discussions with the Contractor and GCL Installer.
- II. Construction problems and solution data sheets
- III. Project Quality Plan – Signatures
- IV. Data on weather conditions
- V. Safety Matters
- VI. Soil cover details
- VII. Signature of Completion Certificate

5.2.4.8.4 AFTER INSTALLATION

The Installer/Contractor is to provide the following within 14 days to the Construction Manager.

- I. A complete Data Pack containing all completed and signed documentation as described herein (Installer/Contractor documentation).
- II. The Installer/Contractor Data Pack
- III. An outline of the project
- IV. A description of the lining system
- V. GCL Material Specification
- VI. Batch and roll numbers of panels used
- VII. A summary of onsite CQA activities, quantities, samples etc.
- VIII. A photographic record of construction
- IX. Discussion of problems and solutions
- X. As built drawings

5.2.5 GEOCELL WITH CEMENT STABILISED SOIL INFILL

5.2.5.1.1 GENERAL

The geomembrane liner system is comprised of both a GCL and 1.5 mm HDPE liner system which are installed with intimate contact being of paramount importance between the two layers to provide an effective barrier system between the water contained with the pollution control dam and the underlying soil. A protection system comprising of a 250mm, 5 kPa soilcrete infill, placed into a geocell layer will serve to protect the HDPE liner system from ultraviolet light, mechanical damage, reduce elevated temperatures on the liner components and provide sufficient confining pressure (of 5 kPa) to the underlying GCL, ensuring a high degree of impermeability once it fully hydrates below the liner.

5.2.5.1.2 MATERIAL SPECIFICATION

5.2.5.1.2.1 GEOCELL

The geocells, as specified below, will be supplied and installed by the main contractor as detailed in the drawings to secure the protection layer on the side slopes and base of the pollution control dam. Installation by the contractor is to take place in consultation with the lining contractor where necessary.

5.2.5.1.2.1.1 CONFORMANCE TESTING

The geocells shall be a high tenacity polypropylene tape, coated with polyethylene and shall comply with the specifications shown below:

Property:	Test Method:	Unit:	Value:
Total mass / unit area	SANS 10221-2007	g / m ²	190
Tensile strength	SANS 10221-2007	kN / m	"Warp" 31
	SANS 10221-2007	kN / m	"Weft" 26
Elongation	SANS 10221-2007	%	"Warp" 13
	SANS 10221-2007	%	"Weft" 11

The geocells are to be in a 200 x 200 mm grid and *250 mm high.

*Note - The 250 mm thick geocell layer may be comprised of two thinner geocell layers, however the sum of the layers must equate to a minimum of a 250 mm overall thickness. Should this option be adopted the proposed layer thicknesses must be approved by the engineer prior to installation.

5.2.5.1.2.1.2 INSTALLATION

The geocells are to be placed as shown in the drawings.

At the time of installation fabric shall be rejected if it has defects, rips, holes, flaws, deterioration or damage incurred during manufacture, transportation, or storage.

The area on which the fabric is to be placed shall be smooth and free of projections or depressions that may cause the fabric to be punctured.

Lay the geocells over the prepared area ensuring that the top of the cells are level with the surrounding terrain and that the highest section of the panel is secured in a lock trench at the top of the embankment or slope (where applicable).

Where the geocells are underlain by earth material, anchor the geocells to the prepared surface with inverted shepherd's crook shaped steel stakes made from 10 mm to 12 mm reinforcing rod, or similar. Every alternate cell should be staked along the edge of each section to ensure that the system is well secured.

Where the geocells are underlain by liner, use of an external tensioning frame must be used. No holes will be permitted in the liner for temporary anchoring purposes. Filling of the geocells to take place in a bottom-upwards manner (i.e. from the toe of the basin, towards the crest).

Join and align the alternate cells of each section of geocells using cable ties (or similar approved connection method) to create a continuous cover over the site. Tension the cover from the highest to the lowest point of the slope by anchoring the bottom edge of the corner to ensure that the individual cells are fully open to receive the fill.

Fill the cells of the entire geocell cover with the soilcrete material to give the required finish to the installation. Fill is to be nominally compacted. The surface should be raked flush to the top of the cells.

Before handover (i.e. completion of an area of responsibility of the work) by the Lining Contractor to any other party, the Lining Contractor, the Engineer and the Third Party Controller shall conduct a detailed walk-through of the lined facility and visually check all seams and non-seamed areas of the geotextile for defects, holes, or signs of damage during installation.

5.2.5.1.2.2 SOILCRETE INFILL

The soilcrete infill will provide both a protective cover to the geomembrane and apply the appropriate confining pressure to the underlying GCL.

5.2.5.1.2.2.1 MATERIALS

The soilcrete is to comprise of washed river sand with a maximum particle size of 5 mm and a blend of Portland cement to achieve a minimum 28-day cube strength of 5 MPa. Sand fraction may not have more than 10% of the sand specimen passing the 0.075mm sieve. A suitable mix design and trial specimens are to be approved by the QCAO and/or engineer prior to placement of the infill taking place.

5.2.5.1.2.2.2 PLACEMENT

The soilcrete infill is to be placed into the geocells in such a manner not to deform or damage the geocell and is to be placed from the basin towards the crest of the facility. Fill the cells of the entire geocell with the soilcrete material, nominally compact and rake flush to the top of the cells. The surface can remain as a rough finish.

The contractor is to allow the soilcrete to cure for 7 days and must ensure

The soilcrete will not be paid for unless properly cured and proof of curing is continuously visible on site and completed. The curing time shall be continued for at least 7 days. A curing compound may be allowed by the QCAO and/or Engineer but must be approved and evidence or documentation of it being safe to use near HDPE geomembranes must be submitted.

5.2.5.2 DOCUMENTATION

5.2.5.2.1 GENERAL

An effective construction quality assurance plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibility for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Construction Manager/CQAO will ensure that all quality assurance requirements have been addressed and satisfied.

5.2.5.2.2 PRIOR TO INSTALLATION

The Installer/Contractor is to provide the following to the Construction Manager/CQAO before installation on site:

- I. Manufacturers conformance certificates
- II. A Method Statement describing the method of installation and quality control documentation to be completed
- III. A Project Quality Plan with organization chart and detailing inspection procedures

5.2.5.2.3 DURING INSTALLATION

The Installer/Contractor is to complete the following:

- IV. Material receipt with roll numbers
- V. Geomembrane and/or geotextile installation acceptance documentation
- VI. Project Quality Plan – Signatures
- VII. Certificate of Acceptance

The Construction Manager's representative is to complete the following daily reports:

- XI. Field notes, including memoranda of meetings and/or discussions with the Contractor and geocell Installer (if they differ).
- XII. Construction problems and solution data sheets
- XIII. Project Quality Plan – Signatures
- XIV. Data on weather conditions
- XV. Safety Matters
- XVI. Soilcrete infill details
- XVII. Soilcrete infill curing details
- XVIII. Signature of Completion Certificate

5.2.5.2.4 AFTER INSTALLATION

The Installer/Contractor is to provide the following within 14 days to the Construction Manager.

- VIII. A complete Data Pack containing all completed and signed documentation as described herein (Installer/Contractor documentation).
- IX. The Installer/Contractor Data Pack
- X. An outline of the project
- XI. A description of the liner protection system
- XII. Geocell and Soilcrete Material Specification
- XIII. Batch and roll numbers of geocells used
- XIV. A summary of onsite CQA activities, quantities, samples etc.
- XV. A photographic record of construction
- XVI. Discussion of problems and solutions
- XVII. As built drawings

5.2.6 GEOGRID

5.2.6.1.1 MATERIAL SPECIFICATION

The geogrid, as specified below, will be supplied and installed by the main contractor as detailed in the drawings to secure the protection layer on the side slopes of the pollution control dam, in the area of the access ramp entering the facility. Installation by the contractor is to take place in consultation with the lining contractor where necessary.

5.2.6.1.2 CONFORMANCE TESTING

The geogrid shall be a transparent polyester (PET) grid and shall comply with the specifications shown below:

Property	Test Method	Unit	Value (long. / trans.)
<i>Secugrid 30/30</i>			
Tensile strength	ISO 10319	kN/m	≥ 30 / ≥ 30
Elongation at maximum tensile strength	ISO 10319	%	≤ 8 / ≤ 8
Tensile strength at 2 % elongation	ISO 10319	kN/m	13.5 / 13.5
Tensile strength at 5 % elongation	ISO 10319	kN/m	24 / 24

The contractor may submit suitable alternatives that may meet the above specification to the QCAO and/or engineer for approval prior to installation.

5.2.6.1.3 INSTALLATION

The geogrid will be supplied and installed by the main contractor as detailed in the drawings. The geogrid is to terminate along its highest boundary in the anchor trench that extends around the facility. The geogrid does not need to be anchored within the basin of the pollution control dam. Installation by the contractor is to take place in consultation with the lining contractor where necessary.

5.2.6.2 DOCUMENTATION

5.2.6.2.1 GENERAL

An effective construction quality assurance plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibility for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Construction Manager/CQAO will ensure that all quality assurance requirements have been addressed and satisfied.

5.2.6.2.2 PRIOR TO INSTALLATION

The Installer/Contractor is to provide the following to the Construction Manager/CQAO before installation on site:

- XVIII. Manufacturers conformance certificates
- XIX. A Method Statement describing the method of installation and quality control documentation to be completed
- XX. A Project Quality Plan with organization chart and detailing inspection procedures

5.2.6.2.3 DURING INSTALLATION

The Installer/Contractor is to complete the following:

- XXI. Material receipt with roll numbers
- XXII. Geomembrane and/or geotextile installation acceptance documentation
- XXIII. Project Quality Plan – Signatures
- XXIV. Certificate of Acceptance

The Construction Manager's representative is to complete the following daily reports:

- XIX. Field notes, including memoranda of meetings and/or discussions with the Contractor and geocell Installer (if they differ).
- XX. Construction problems and solution data sheets
- XXI. Project Quality Plan – Signatures
- XXII. Data on weather conditions
- XXIII. Safety Matters
- XXIV. Signature of Completion Certificate

5.2.6.2.4 AFTER INSTALLATION

The Installer/Contractor is to provide the following within 14 days to the Construction Manager.

- XXV. A complete Data Pack containing all completed and signed documentation as described herein (Installer/Contractor documentation).
- XXVI. The Installer/Contractor Data Pack
- XXVII. Geogrid Material Specification
- XXVIII. Batch and roll numbers of geogrid used
- XXIX. A summary of onsite CQA activities, quantities, samples etc.
- XXX. A photographic record of construction
- XXXI. Discussion of problems and solutions
- XXXII. As built drawings

6 DOCUMENTATION

An effective CQA plan depends largely on recognition of all construction activities that must be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Construction Manager will ensure that all quality assurance requirements have been addressed and satisfied. No section of the liner system may be covered up until the CQAO observes and approves the completed section of the liner system and assures that all CQA documentation has been completed.

6.1 DAILY RECORD KEEPING

Standard reporting procedures shall include preparation of daily reports that, at a minimum, will consist of:

- field notes, including memoranda of meetings and/or discussions with the Contractor and GSM Installer.
- observation logs, and testing data sheets; and
- construction problem and solution data sheets.

This information must be regularly submitted to and reviewed by the CQAO and the Construction Manager.

6.2 OBSERVATION LOGS AND TESTING DATA SHEETS

Observation logs and testing data sheets shall be prepared weekly. At a minimum, these logs and data sheets shall include the following information:

- an identifying log/sheet number of cross-referencing and document control.
- date, client name, project name, location, and other identification;
- data on weather conditions;
- a site plan showing all active work areas and test locations;
- descriptions and locations of on-going construction;

- equipment and personnel in each work area, including those of all related sub-contractors;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where tests were undertaken and samples taken;
- a summary of test results;
- calibrations of test equipment, and actions taken as a result of any non-conformance;
- off-site materials received, including quality verification documentation;
- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of non-conformance; and
- signatures of the CQA Officer and the CQA Monitors.

6.3 CONSTRUCTION PROBLEM AND RESOLUTION DOCUMENTATION

Any construction problem which cannot be resolved between the Installer, contractor, and CQAO may require a special meeting in order to resolve the problem. The problem should be discussed with the Employers Agent, CQAO, and Design Engineer if a design issue is involved. Specific written documentation of that problem should be prepared, if warranted, and will generally include the following information:

- Detailed description of the problem
- Location and cause of the problem
- How and when the situation or deficiency was identified
- How the problem was resolved
- Any measures taken to prevent similar problems in the future
- Signature of the Construction Manager and CQAO

The CQA Officer shall incorporate all of these logs in the CQA Final Report

6.4 PHOTOGRAPHIC DOCUMENTATION

All phases of construction relating to this plan shall be sufficiently photographed by the CQAO. Photographs shall be identified by separate photographic log by location, time, date, and name of the person taking the photograph. A camera which records the time and date shall be used. Representative photographs will be included in the certification report.

The CQA Officer shall incorporate all of these logs in the CQA Final Report.

6.5 DESIGN AND SPECIFICATION CHANGES

If it is necessary to address Construction Drawings and/or Construction Specification changes, modifications, or clarifications during construction, the CQAO or Construction Manager will inform the Construction Manager who will notify the Design Engineer. Construction Drawing and Construction Specification changes shall only be made with written agreement from the Construction Manager and Design Engineer, and approval of the Employer if required.

The CQA Officer shall incorporate all these logs in the CQA Final Report.

7 CQA FINAL REPORT

7.1 SUBMISSION OF REPORT

The CQA Final Report, will be submitted by the Construction Manager to the Employer within 40 days of completion of installation of the lining system.

7.2 CQA FINAL REPORT CONTENTS

At a minimum the CQA Final Report shall contain the following information:

- An outline of the project
- A description of the lining/system
- Reference to the CQA Plan and other documents used
- Geosynthetic membrane and other geosynthetic materials specifications
- A summary of on-site CQA activities and quantities (samples, failing results)
- A photographic record of construction
- Manufacturer/GSM Installer Compliance Agreement
- Subgrade acceptance certificates
- Copies of all logs
- All test results
- Discussion of problems and solutions
- Changes to the Construction Drawings or Construction Specifications and the justification for these changes
- Record drawings
- Certificate statement

7.3 RECORD DRAWINGS

4 separate layouts records will be surveyed, and a detailed record kept of the panel placement for the following:

- 1) Geosynthetic Clay Liner (GCL) Panel Layout
- 2) HDPE Liner Panel Layout,
- 3) Protection Geotextile Panel Layout, and
- 4) Wrinkle Formation Layout.

The record drawings above will include at least the above (as applicable):

- The locations of all geosynthetic membrane joints and the types of joints. Especially transverse joints on slopes where the slope length exceeds the GCL roll length,
- GSM/GCL panel and roll numbers, and GSM/GCL type,
- The location of all geosynthetic membrane repairs and the types of repairs,
- Toes and Crests of slopes,

- Location of anchor trenches,
- Location and numbers of any GSM destructive test sample sites,
- Construction details and tolerances that differ from as-designed details.

In addition to the above, it will be a requirement to submit an initial panel layout for each of the liner elements for review by the Design Engineer and CQAO prior to commencing with the Works. The Contractor's attention is also drawn to the requirements of SANS 10409:2020 and must comply with the requirements contained within over and above the requirements above.

7.4 GEOMEMBRANE GUARANTEE

A geomembrane guarantee is not required. Should the manufacturer offer a guarantee on materials purchased, a copy of the guarantee shall be submitted to the Construction Manager.

LIST OF APPENDICES

Appendix A: Parties involved in the CQA implementation

APPENDIX A: PARTIES INVOLVED IN THE CQA IMPLEMENTATION

The responsible parties for the Lafarge Pollution Control Dam with regards to being the facility owner/developer are indicated below:

EMPLOYER/OWNER

The Employer in terms of the Construction Contract, as well as the facility Owner/Operator is Lafarge Industries South Africa (PTY) LTD Lichtenburg. The key contact persons on behalf of the Employer/Owner are detailed in Table 16 below:

Table 13: Employer/Owner Project Professional Team Members (key persons)

PARTY		Representative	Role	E-Mail Address
FACILITY OWNER/ DEVELOPER	LAFARGE INDUSTRIES OF SOUTH AFRICA (PTY)LTD	Millicent Siwele	Project Manager	millicent.siwele@lafarge.com
		Joggie Van Der Westhuizen	Project Leader	joggie.vanderwesthuizen@lafarge.com
		JG AFRIKA	Project Representative/ Contract Manager	
		Uneysa Taljard	Environmental	uneysa.taljard@lafarge.com
		Lefentse Makoko	Lichtenburg Area Manager	lefentse.makoko@lafarge.com

ENGINEER

JG Afrika were appointed by Lafarge Lichtenberg to undertake the preliminary design of the proposed **Lafarge Pollution Control Dams, and affiliated stormwater related infrastructure. The professional team that worked on the project included the following key members, at the time of writing this report (see below). The responsible Pr Eng signing off on the project for the purposes of the application to the approval authority is as follows:**

Name: Jan Clare Norris,

PrEng Registration: 980198

PARTY		Representative	Role	E-mail Address
APPOINTED PROFESSIONAL TEAM	JG Afrika	Jan Norris PrEng	Project Director, Specialist Geotech Engineer	NorrisJ@jgafrika.com
		Guy Robertson PrEng	Design Engineer	guyr@pegasys.co.za
		Graham Pearson PrEng	Structural Engineer	PearsonG@jgafrika.com
		Mukovhe Muvhali	Civil Engineer	MuvhaliM@jgafrika.com
		Mark Miller	Civil Engineer	MillerM@jgafrika.com

CQA OFFICER

A CQA Officer will be provided by JG Afrika.

Table 14: CQA Personnel

PARTY		Representative	Role
APPOINTED CQA Team	JG Afrika	TBC	TBC

MAIN CONTRACTOR

A Contractor has not yet been identified or appointed for the Construction of the Lafarge PCDs and will be appointed using a competitive tender process once the design has been completed and approval for the design has been obtained from the regulatory authority. Naturally, the Geomembrane Installer has yet to be confirmed/proposed, however approval of the Geomembrane Installer will be subject to the conditions outlined in the CQA document.:

Table 15: Employer/Owner Project Professional Team Members (key persons)

PARTY		Representative	Role	E-Mail Address
CONSTRUCTION CONTRACTOR	MAIN/CIVIL CONTRACTOR	TBC	Contracts Manager	
		TBC	Site Agent	
	GMB INSTALLER	TBC	Contract Manager	
		TBC	Installer	
	GMB MANUFACTURER	TBC	Contract Manager	
	GCL INSTALLER	TBC	Contract Manager	
	GCL MANUFACTURER	TBC	Design Manager	
	GEOTEX INSTALLER	TBC	Contracts Manager	
	GEOTEX MANUFACTURER	TBC	Design Manager	
	QA Laboratory	TBC	Lab Technician	