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MMAKAU COAL

Report

Feasibility Study (Volume 1)

Mmakau Coal (Pty) Ltd

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CLASSIFICATION

CONFIDENTIAL

Chapter 20 Construction Quality Assurance Plan

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20 CONSTRUCTION QUALITY ASSURANCE PLAN

20.1 INTRODUCTION AND PURPOSE

A Construction Quality Assurance (CQA) Plan is required in terms of the National Environmental Management: Waste Amendment Act (NEMWAA), 2014 (Act No, 26 of 2014) for mine residue facility (MRF). A CQA Plan details the testing requirements, responsible parties, inspection protocols and documentation required for the proposed construction of the barrier system at the base of the MRF. CQA is carried out to ensure that the works have been undertaken to the highest of quality assured standards, and in accordance with the agreed Technical Specification and Works Documents. Furthermore, the CQA program is intended to provide a level of confidence to the Owner, Engineer, Regulator and the public that the completed project has been constructed in accordance with the approved specifications and approved works documents.

This CQA Plan has been prepared to detail the installation and testing quality control procedures that will be followed during construction of the barrier system at the base of the proposed MRF and ROM Stockpile at Schurvekop. The CQA Plan must be read in conjunction with the Technical Specifications and other Contract Documents.

20.2 PARTIES INVOLVED WITH CONSTUCTION QUALITY ASSURANCE

20.2.1 Owner

The Owner of this project is Mmakau Coal (Pty) Ltd.

20.2.2 Construction Manager

The Construction Manager is responsible for managing the construction and implementation of the Drawings, and Technical Specifications for the project work. The Construction Manager is selected/ appointed by the Owner.

20.2.3 Engineer

The Engineer is responsible for the design, Drawings, and Technical Specifications for the project work. The Engineer of Record shall be a qualified engineer, registered as a professional engineer with the Engineering Council of South Africa. The Engineer should have expertise, which demonstrates significant familiarity with piping, geosynthetics and soils, as appropriate, including design and construction experience related to liner systems.

20.2.4 Contractor

In this CQA Plan, Contractor refers to an independent party or parties, contracted by the Owner, performing the work in general accordance with this CQA Plan, the Drawings, and the Technical Specifications. The Contractor will be responsible for the installation of the soils, pipe, drainage aggregate, and geosynthetic components of the liner systems. This work will include subgrade preparation, anchor trench excavation and backfill, placement of drainage aggregate for the slurry drain system, installation of piping, placement of cast-in-place concrete, and coordination of work with the Geosynthetic Installer and other subcontractors. The Contractor will be responsible for constructing the barrier system and appurtenant components in general accordance with the Drawings and complying with the quality control requirements specified in the Technical Specifications.

Qualifications

Qualifications of the Contractor are specific to the construction contract. The Contractor should have a demonstrated history of successful earthworks, piping, and liner system construction and shall maintain current state and federal licenses as appropriate.

20.2.5 Resin Supplier

Responsibilities

The Resin Supplier produces and delivers the resin to the Geosynthetics Manufacturer.

Qualifications

Qualifications of the Resin Supplier are specific to the Manufacturer's requirements. The Resin Supplier will have a demonstrated history of providing resin with consistent properties.

20.2.6 Manufacturers

Responsibilities

The Manufacturers are responsible for the production of finished material (geomembrane, geotextile, and pipe) from appropriate raw materials.

Qualifications

The Manufacturer(s) will be able to provide sufficient production capacity and qualified personnel to meet the demands of the project. The Manufacturer(s) must be a well-established firm that meets the requirements identified in the Technical Specifications.

20.2.7 Geosynthetic Installer

Responsibilities

The Geosynthetic Installer/Lining Contractor is responsible for field handling, storage, placement, seaming, ballasting or anchoring against wind uplift, and other aspects of the geosynthetic material installation. The Geosynthetic Installer/Lining Contractor may also be responsible for specialized construction tasks (i.e., including construction of anchor trenches for the geosynthetic materials).

If required, the Geosynthetic Installer/Lining Contractor shall conduct tests to confirm that the geomembrane liner offered is resistant for the duration of the guarantee period to the effects of the liquids intended for storage. The Engineer may, at his discretion, request that immersion tests be undertaken for a period of 28 days minimum for the proposed lining in a liquid sample provided by the client. These samples will be tested for changes in physical and mechanical properties and compared with those immersed in water over the same period of time.

Qualifications

The Geosynthetic Installer/Lining Contractor will be trained and qualified to install the geosynthetic materials of the type specified for this project. The Geosynthetic Installer/Lining Contractor shall meet the qualification requirements identified in the Technical Specifications.

20.2.8 Resident Engineer

Responsibilities

The Resident Engineer will act as the CQA Consultant and is a party, independent from the Owner, Contractor, Manufacturer, and Geosynthetic Installer, who is responsible for observing, testing, and documenting activities related to the CQC and CQA of the earthwork, piping, and geosynthetic components used in the construction of the Project as required by this CQA Plan and the Technical Specifications. The Resident Engineer will also be responsible for issuing a CQA report at the completion of the Project construction, which documents construction and associated CQA activities. The CQA report will be signed and sealed by the CQA Officer who will be a Professional Engineer.

Qualifications

The Resident Engineer will be experienced with earthworks and installation of geosynthetic materials similar to those materials used in construction of the Project. The Resident Engineer will be experienced in the preparation of CQA documentation including CQA Plans, field documentation, field testing procedures, laboratory testing procedures, construction specifications, construction Drawings, and CQA reports.

The Resident Engineer will be specifically familiar with the construction of earthworks, piping, and geosynthetic lining systems.

20.2.9 Surveyor

The surveyor is a party, independent from the Contractor, Manufacturer, and Geosynthetic Installer, that is responsible for surveying, documenting, and verifying the location of all significant components of the Work. The Surveyor's work is coordinated and employed by the Contractor. The Surveyor is responsible for issuing Record Drawings of the construction.

20.2.10 CQA Laboratory

Responsibilities

The CQA Laboratory is a party, independent from the Contractor, Manufacturer, Geosynthetic Installer, that is responsible for conducting tests in general accordance with ASTM and other applicable test standards on samples of geosynthetic materials, soil, and in the field and in either an on-site or off-site laboratory.

Qualifications

The CQA Laboratory will have experience in testing soils and geosynthetic materials and will be familiar with ASTM and other applicable test standards. The CQA Laboratory will be capable of providing test results within a maximum of seven days of receipt of samples and will maintain that capability throughout the duration of earthworks construction and geosynthetic materials installation. The CQA Laboratory will also be capable of transmitting geosynthetic destructive test results within 24 hours of receipt of samples and will maintain that capability throughout the duration of geosynthetic material installation.

20.3 DEFECTS IDENTIFICATION AND RECTIFICATION

If a defect is discovered in the work, the Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Engineer will determine the extent of the defect area by additional tests, observations, a review of records, or other means that the Engineer deems appropriate.

After evaluating the extent and nature of a defect, the Engineer will notify the Construction Manager and schedule appropriate re-tests when the work defect is corrected by the Contractor.

The Contractor will correct the defect to the satisfaction of the Engineer. Defect corrections will be monitored and documented.

20.4 SITE AND PROJECT PROTOCOL

20.4.1 Project Coordination Meetings

Meetings of key project personnel are necessary to assure a high degree of quality during construction and to promote clear, open channels of communication. Therefore, Project Coordination Meetings are an essential element in the success of the project. Several types of Project Coordination Meetings are described below, including:

(i) Pre-construction meetings;

(ii) Progress meetings; and

(iii) Problem or work defect meetings.

20.4.1.1 Pre-Construction Meeting

Pre-Construction Meeting will be held at the site prior to construction of the Project. At a minimum, the Pre-Construction Meeting will be attended by the Contractor, the Geosynthetic Installer's Construction Manager, the Engineer, and the Construction Manager.

Specific items for discussion at the Pre-Construction Meeting include the following:

- appropriate modifications or clarifications to the CQA Plan;
- the Drawings and Technical Specifications;
- the responsibilities of each party;
- lines of authority and communication;
- methods for documenting and reporting, and for distributing documents and reports;
- acceptance and rejection criteria;
- protocols for testing;
- protocols for handling defects, repairs, and re-testing;
- the time schedule for all operations;
- procedures for packaging and storing archive samples;
- panel layout and numbering systems for panels and seams;
- seaming procedures;
- repair procedures; and
- soil stockpiling locations.

The Construction Manager will conduct a site tour to observe the current site conditions and to review construction material and equipment storage locations. A person in attendance at the meeting will be appointed by the Construction Manager to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

20.4.1.2 Progress Meetings

Progress meetings will be held between the Engineer, the Contractor, Construction Manager, and other concerned parties participating in the construction of the project. This meeting will include discussions on the current progress of the project, planned activities for the next week, and revisions to the work plan and/or schedule. The meeting will be documented in meeting minutes prepared by a person designated by the Resident Engineer at the beginning of the meeting. Within 2 working days of the meeting, draft minutes will be transmitted to representatives of parties in attendance for review and comment. Corrections and/or comments to the draft minutes shall be made within 2 working days of receipt of the draft minutes to be incorporated in the final meeting minutes.

20.4.1.3 Problem or Work Deficiency Meeting

A special meeting will be held when and if a problem or defect is present or likely to occur. The meeting will be attended by the Contractor, the Construction Manager, the Engineer, and other parties as appropriate The purpose of the work defect meeting is to define and resolve the problem or work defect as follows:

- define and discuss the problem or defect;
- review alternative solutions;
- select a suitable solution agreeable to all parties; and
- implement an action plan to resolve the problem or defect.

The Construction Manager will appoint one attendee to record the discussions and decisions of the meeting. The meeting record will be documented in the form of meeting minutes and copies will be distributed to all affected parties. A copy of the minutes will be retained in facility records.

20.5 DOCUMENTATION

20.5.1 Overview

An effective CQA Plan depends largely on recognition of all construction activities that should 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 Engineer will document those quality assurance requirements which have been addressed and satisfied.

The Engineer will provide the Construction Manager with signed descriptive remarks, data sheets, and logs to verify that monitoring activities have been carried out. He will further maintain, a complete file of Drawings and Technical Specifications, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents at the construction site.

20.5.2 Daily Recordkeeping

Preparation of daily CQA documentation will consist of daily field reports prepared by the Resident Engineer which may include CQA monitoring logs and testing data sheets. This information may be regularly submitted to and reviewed by the Construction Manager. Daily field reports will include documentation of the observed activities during each day of activity. The daily field reports may include monitoring logs and testing data sheets. At a minimum, these logs and data sheets will include the following information:

- the date, project name, location, and other identification;
- a summary of the weather conditions;

- a summary of locations where construction is occurring;
- equipment and personnel on the project;
- a summary of meetings held and attendees;
- a description of materials used and references of results of testing and documentation;
- identification of defective work and materials;
- results of re-testing corrected “defective work;”
- an identifying sheet number for cross referencing and document control;
- descriptions and locations of construction monitored;
- type of construction and monitoring performed;
- description of construction procedures and procedures used to evaluate construction;
- a summary of test data and results;
- calibrations or re-calibrations of test equipment and actions taken as a result of recalibration;
- decisions made regarding acceptance of units of work and/or corrective actions to be taken in instances of substandard testing results;
- a discussion of agreements made between the interested parties which may affect the work; and
- signature of the respective Engineer and Construction Manager.

20.5.3 Construction Problems and Resolution Data Sheets

Construction Problems and Resolution Data Sheets, to be submitted with the daily field reports prepared by the Resident Engineer, describing special construction situations, will be cross-referenced with daily field reports, specific observation logs, and testing data sheets and will include the following information, where available:

- An identifying sheet number for cross-referencing and document control;
- A detailed description of the situation or defect;
- The location and probable cause of the situation or defect; how and when the situation or
- Defect was found or located;
- Documentation of the response to the situation or defect;
- Final results of responses;
- Measures taken to prevent a similar situation from occurring in the future; and
- Signature of the Engineer and a signature indicating concurrence by the Construction Manager.

The Construction Manager will be made aware of significant recurring non-conformance with the Drawings, Technical Specifications, or CQA Plan. The cause of the non-conformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Construction Manager for approval. When this type of evaluation is made, the results will be documented and any revision to procedures or specifications will be approved by the Contractor and Engineer.

A summary of supporting data sheets, along with final testing results and the Resident Engineer’s approval of the work, will be required upon completion of construction.

20.5.4 Photographic Documentation

Photographs will be taken and documented in order to serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Construction Manager upon completion of the project. Photographic reporting data sheets, where used, will be cross-referenced with observation and testing data sheet(s), and/or construction problem and solution data sheet(s).

20.5.5 Design and/or Specifications Changes

Design and/or specifications changes may be required during construction. In such cases, the Engineer will notify the Engineer. Design and/or specification changes will be made with the written agreement of the Engineer and will take the form of an addendum to the Drawings and Technical Specifications.

20.5.6 CQA Report

At the completion of the Project, the Engineer will submit a CQA report to the Owner, which will be signed by the Engineer. The CQA report will acknowledge: (i) that the work has been performed in compliance with the Drawings and Technical Specifications; (ii) physical sampling and testing has been conducted at the appropriate frequencies; and (iii) that the summary document provides the necessary supporting information. At a minimum, this report will include:

- A summary report describing the CQA activities and indicating compliance with the Drawings and Technical Specifications;
- A summary of CQA/CQC testing, including failures, corrective measures, and retest results;
- Contractor and Installer personnel CV's and qualifications as necessary;
- Documentation that the geomembrane trial seams were performed in general accordance with the CQA Plan and Technical Specifications;
- Documentation that non-destructive tests were carried out on field seams using a method in general accordance with the applicable test standards;
- Documentation that non-destructive testing was monitored by the Resident Engineer, that the Engineer informed the Geosynthetic Installer of any required repairs, and that the Engineer monitored the seaming and patching operations for uniformity and completeness;
- Records of sample locations, the name of the individual conducting the tests, and the results of tests;
- Record Drawings as provided by the Surveyor;
- Daily filed reports.

The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., plan dimensions and appropriate elevations). Record Drawings and required base maps will be prepared by a qualified Professional Land Surveyor. These documents will be reviewed by the Engineer and included as part of the CQA Report.

20.6 EARTHWORKS

20.6.1 Introduction

Earthworks requirements associated with the MRF's barrier system construction are detailed in the works Technical Specification. Primarily, this will consist of excavation and stockpiling of unsuitable in-situ materials from the proposed MRF footprint. Topsoil will be stripped and stockpiled separately for later use.

Earthworks activities will include excavating and trimming in preparation to receive suitable engineered fill. Bulk excavation and placement of engineered fill will be undertaken to achieve required formation and top of engineered clay sub-base levels. Additional earthworks will include construction of perimeter starter walls and paddock walls. Specific requirements for each earthwork component are detailed in the Technical Specification and Drawings.

20.6.2 General Setting Out

The Contractor shall be responsible for maintaining accurately ascertained site datum levels. He shall further ensure that all level control and setting out of the works is executed in accordance with the survey data given on the construction drawings. Immediately following the issue of the order to commence, the Contractor shall carry out and record a check level grid of the site of works, in order to accept the contour levels shown on the drawings. Any discrepancies causing non-acceptance by the Contractor of the levels shown on the drawings are to be pointed out to the Engineer within two weeks of the above order being given, and the alterations checked and agreed with the Engineer. Failing this, the original levels as shown on the construction drawings will be deemed correct and acceptable. In addition to the above, the following survey tasks shall be undertaken by the Contractor for agreement with the Engineer.

- Ground levels shall be recorded at 10 m intervals on the centre line, upstream and downstream toe positions of all embankments and fills after site clearance and again after removal of unsuitable material where present. In the case of large embankments or fills the Engineer may specify that the intensity of recorded levels be increased to that of a 5 m grid.
- Ground levels shall be recorded at 2.5 m and 5.0 m intervals on the entire line left and right bank positions of all trenches, canals and drains prior to excavation and again on completion of the excavation to the required depths and grades.
- Ground levels shall be recorded on a 10 m grid over discard borrow areas. After removal of unsuitable material and/or topsoil and/or fill material as required, the Contractor shall re- survey the ground and record levels as described above. The grids and lines before and after soil removal shall be coincident in plan.

All survey submitted by the Contractor is to be approved in writing by the Engineer before being considered valid as a basis of measurement.

The Contractor is to inform the Engineer in writing upon the completion of impoundment walls and trenches to design elevations and cross-sections. Thereafter, a check may be carried out by the Engineer's Representative to verify these elevations and cross-sections.

20.6.3 Materials

The Resident Engineer shall undertake the following as part of his duties:

- Inspect proposed engineered fill material sources area and/or stockpiled prior to use and advise the Construction Manager of the presence of any unsuitable material.
- Review all test results/reports provided by the Contractor for the proposed engineered fill material to verify that the material is uniform and conforms to the Technical Specification.
- Provide updates to the Construction Manager regarding consistency of source material and whether additional testing is required if the material appears to have changed significantly.

20.6.4 Inspection and Monitoring

The Construction Manager shall be solely responsible for the satisfactory completion of all CQA testing activities in accordance with the Specification and this CQA Plan. The site clearance, soils separation and bulk earthworks shall be undertaken to the satisfaction of the Construction Manager or designated representative.

The Construction Manager will be responsible for confirming that the finished excavation and all liner system fill levels are in general compliance with the Drawings and Specifications. This may be undertaken by the Contractor providing survey data to cross check against the levels stated on the design drawings. Levels are to be within the specified tolerances.

Material deemed unsuitable and not meeting the Specification shall be removed from the works as soon as practicable and placed in stockpile, at the direction of the Construction Manager. The excavated ground surface to receive fill shall be prepared to the satisfaction of the Resident Engineer and in accordance with the shear strength requirements stated in the Specification. Subsequent fill shall be placed, spread, moisture conditioned if necessary and compacted in accordance with the Specification and as recommended by the Construction Manager and Resident Engineer.

During periods of adverse weather such as heavy rainfall, fill operations shall not be resumed until observations and field tests by the Resident Engineer indicate the moisture content and density of the previously placed fill and/or materials intended for placement are within the limits required within the Specification and CQA Plan.

Compacted fill placement shall be undertaken in accordance with the requirements of the Technical Specification.

20.6.5 Inclement Weather

The Resident Engineer shall ensure that earthworks do not occur during periods of excessive rain or other poor weather conditions that may be detrimental to the previously undertaken works and impede progress and performance of on-going works

20.6.6 Contractors Plant

The Resident Engineer shall visually inspect and verify the Contractors plant and equipment proposed for the placement, compaction and trimming of the earthworks component of the works to ensure they meet the requirements of the Specification and the approved Contractors work method statements.

20.6.7 General Excavation

During the general excavation phase within the proposed MRF footprint, the Resident Engineer shall ensure the following:

- Unsuitable materials, whether inhomogeneous, water saturated or contaminated and generally not meeting the requirements of the Technical Specification shall be excavated and disposed by the Contractor in locations indicated by the Owner;
- Temporary excavated faces shall be left in a safe, stable condition with fencing or barrier tape;
- Excavated slopes shall be finished in conformance with the required lines and grades;
- All debris and loose material is removed from the completed trimmed surfaces; and

- The Contractor has implemented protective measures to ensure that the excavation areas are not damaged during periods of inclement weather.

20.6.8 Filling

During the general filling phase within the landfill footprint, the Resident Engineer shall ensure the following:

- Loose un-compacted lifts are placed no greater than the maximum allowable thickness stated in the Technical Specification;
- Fill contains no large clods, rocks, debris or other non-compliant material stipulated within the Technical Specification;
- Fill material is placed to the lines and levels shown in the Works Documents; and
- Slippage of fill emplacement and compaction plant does not occur on side slopes especially when any fill layer overlays geosynthetics.

20.6.9 Compaction

During the compaction of engineered fill phase, the CQA Engineer shall ensure the following:

- Ensure no deleterious materials exist within the un-compacted layer prior to compaction;
- Ensure appropriate plant and equipment is used by the contractor to undertake sufficient compaction;
- Verify and ensure the specified minimum number of passes are being made over all areas and over each lift of engineered fill;
- Ensure sufficient compactive effort is afforded to all edges and difficult to access fill emplacement areas;
- Visually observe and ensure compaction around all penetrations ensuring no voids or un-compacted areas remain;
- Verify the surface of each lift is adequately scarified prior to emplacement of any subsequent lift of fill;
- Inspect any pipework that may penetrate fill layers for damage due to placement and compaction equipment; and
- Ensure low ground pressure equipment is used when compaction is required over piping, geosynthetics, leachate drainage aggregate or similar.

20.6.10 Subgrade

The Resident Engineer shall inspect the completed subgrade and verify the following:

- The subgrade is smooth, free of voids and protrusions and composed of compliant homogeneous fill materials;
- The Resident Engineer shall witness proof rolling to assess the soundness and suitability of the subgrade based on the requirements of the Specification;
- The elevation of the subgrade surface is correct and to the Works Documents;
- The subgrade provides a stable surface for the overlying geosynthetics;
- All construction stakes, hubs or other items used for grade control and/or verification have been removed;
- Soft spots within the subgrade have been removed and replaced with suitable compacted fill;
- Suitable protection measures are installed to protect the subgrade from degradation or damage; and
- The subgrade is kept free of all debris and deleterious materials.

20.6.11 Tolerances

The Resident Engineer shall review as-built survey data of the completed surfaces to confirm layer thickness is within the allowable tolerance stated within the Technical Specification.

20.6.12 Anchor Trenches

The Resident Engineer shall inspect and verify the following:

- The anchor trench has been constructed to the required dimensions and profile;
- Corners of the anchor trench are slightly rounded to avoid sharp apexes that would otherwise damage geosynthetics;
- No loose fill or debris from the anchor trench side walls are left in the base of the formed anchor trench;
- Any standing water within the anchor trench is removed prior to the deployment of geosynthetics;
- Geosynthetic layers have been placed correctly within the anchor trench;
- Construction debris, waste, offcuts, geosynthetic inner rolls or other materials are removed from the anchor trench prior to deployment of geosynthetics;
- The anchor trench is backfilled in required layers with suitable approved fill placed at the specified moisture content and density ensuring no damage to the emplaced geosynthetics.

20.6.13 Conformance Testing

Construction quality assurance testing for engineered fill shall be carried out by an independent ISO/SANS 17025 accredited testing laboratory in accordance with the Technical Specification.

The Resident Engineer shall arrange with the Contractor for conformance testing of the materials used in the Works, in accordance with this CQA Plan and the Technical Specification. Samples shall be collected at locations designated by the Resident Engineer and all conformance sampling shall be witnessed by the Resident Engineer to ensure that all samples are taken, accurately labelled and packaged in accordance with the Technical Specification and this CQA Plan.

Field tests shall be conducted by suitably qualified and experienced personnel.

The Resident Engineer shall;

- Ensure moisture content and in-situ density tests are performed at the specified frequency over a representative spread of the construction area;
- Conduct additional tests at any time that in the opinion of the Resident Engineer, additional testing is required and/or a deficiency is suspected;
- The Contractor performs corrective action as a result of failed tests in compliance with the Works Documents and submits documentation describing the corrective measures taken;

20.6.14 As-Built Levels

The Resident Engineer will be required to continually review construction levels and positioning with respect to the design drawings and review the Contractor provided final as-built survey data to verify conforming lines, levels and layer thickness are within the allowable tolerance given within the Technical Specification.

Following a thorough re-working of a failed area, retesting will be performed by the Resident Engineer to evaluate whether the re-worked area meets the requirements of the Technical Specification.

20.6.15 Acceptance and Signoff

At the hold point for completion of earthworks, the Superintendent shall formally sign off the activity prior to the Contractor undertaking subsequent activities. The Resident Engineer shall provide a recommendation to the Construction Manager on whether in their opinion, the works have been completed in accordance with the Technical Specification. In order to provide the recommendation, the Resident Engineer shall consider the following:

- Confirm lines, levels and falls have been achieved;
- Review of CQA test results confirming compliant results have been received;
- Detailed monitoring and inspections have been undertaken.

20.7 DRAINAGE AGGREGATE

20.7.1 Introduction

This section prescribes the CQA activities to be performed to monitor that drainage aggregates are constructed in general accordance with Drawings and Technical Specifications. The drainage aggregates construction procedures to be monitored by the Resident Engineer include drainage aggregate placement.

20.7.2 Testing Activities

Aggregate testing will be performed for material qualification and material conformance. These two stages of testing are defined as follows:

- Material qualification tests are used to evaluate the conformance of a proposed aggregate source with the Technical Specifications for qualification of the source prior to construction.
- Aggregate conformance testing is used to evaluate the conformance of a particular batch of aggregate from a qualified source to the Technical Specifications prior to installation of the aggregate.

The Contractor will be responsible for submitting material qualification test results to the Construction Manager and to the Resident Engineer for review. The Laboratory will perform the conformance testing and CQC testing. Aggregate testing will be conducted in general accordance with the current versions of the corresponding American Society for Testing and Materials (ASTM) test procedures.

20.7.2.1 Sample Frequency

The frequency of aggregate testing for material qualification and material conformance is presented in Table 20-1 and Table 20-2. The actual frequency of testing required may be increased by the Resident Engineer, if variability of materials is noted at the site, or during adverse conditions, or to isolate failing areas of the construction.

Table 20-1: Test procedures for evaluation of aggregate

Test Method	Description	Test Standard
Sieve Analysis	Particle Size Distribution of Fine and Coarse Aggregate	ASTM C 136
Hydraulic Conductivity	Permeability of Aggregates	ASTM D 2434

Test Method	Description	Test Standard
(Rigid Wall Permeater)		

Table 20-2: Minimum aggregate testing frequency for conformance testing

Test	Test Method	Test Standard
Sieve Analysis	ASTM C 136	1 per 3 800 m^3
Hydraulic Conductivity	ASTM D 2434	1 per 7 600m^3

20.7.2.2 Sample Selection

With the exception of qualification samples, sampling locations will be selected by the Resident Engineer. Samples to test for conformance will be obtained from borrow pits and/or stockpiles of material. The Contractor must plan the work and make aggregate available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The Resident Engineer must document sample locations so that failing areas can be immediately isolated. The Resident Engineer will follow standard sampling procedures to obtain representative samples of the proposed aggregate materials.

20.7.3 CQA Monitoring Activities

20.7.3.1 Drainage Aggregate

The Resident Engineer will monitor and document the installation of the drainage aggregates. In general, monitoring of the installation of drainage aggregate includes the following activities:

- Reviewing of the material qualification test results provided by the Contractor;
- Sampling and testing for conformance of the materials to the Technical Specifications;
- Documenting that the drainage aggregates are installed using the specified equipment and procedures;
- Documenting that the drainage aggregates are constructed to the lines and grades shown on the Drawings; and
- Monitoring that the construction activities do not cause damage to underlying geosynthetic materials.

20.7.4 Defects

If a defect is discovered in the drainage aggregates, the Resident Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Resident Engineer will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that he deems appropriate.

20.7.4.1 Notification

After evaluating the extent and nature of a defect, the Resident Engineer will notify the Construction Manager and Contractor and schedule appropriate re-tests when the work defect is to be corrected.

20.7.4.2 Repairs and Re-Testing

The Contractor will correct the defect to the satisfaction of the Resident Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Resident Engineer will develop and present to the Construction Manager suggested solutions for approval.

Re-tests recommended by the Resident Engineer shall continue until it is verified that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The Resident Engineer will also verify that installation requirements are met and that submittals are provided.

20.8 GEOMEMBRANE

20.8.1 General

This section discusses and outlines the CQA activities to be performed for high density polyethylene (HDPE) geomembrane installation. The Resident Engineer will review the Drawings, Technical Specifications, and any approved Addenda regarding this material.

20.8.2 Geomembrane Material Conformance

20.8.2.1 Introduction

The Resident Engineer will document that the geomembrane delivered to the site meets the requirements of the Technical Specifications prior to installation. The Resident Engineer will:

- Review the manufacturer's submittals for compliance with the Technical Specifications;
- Document the delivery and proper storage of geomembrane rolls; and
- Conduct conformance testing of the rolls before the geomembrane is installed.

The following sections describe the CQA activities required to verify the conformance of geomembrane.

20.8.2.2 Review of Quality Control

Material Properties Certification

The Manufacturer will provide the Construction Manager and the Resident Engineer with the following:

- Property data sheets, including, at a minimum, all specified properties, measured using test methods indicated in the Technical Specifications, or equivalent;
- Sampling procedures and results of testing.

The Resident Engineer will document that:

- The property values certified by the Manufacturer meet all of the requirements of the Technical Specifications; and
- The measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

Geomembrane Roll MQC Certification

Prior to shipment, the Manufacturer will provide the Construction Manager and the Resident Engineer with MQC certificates for every roll of geomembrane provided. The MQC certificates will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the production manager.

The MQC certificates shall include:

- Roll numbers and identification; and
- Results of MQC tests - as a minimum, results will be given for thickness, specific gravity, carbon black content, carbon black dispersion, tensile properties, and puncture resistance evaluated in general accordance with the methods indicated in the Technical Specifications or equivalent methods approved by the Construction Manager.

The Resident Engineer will document that:

- MQC certificates have been provided at the specified frequency, and that the certificates identify the rolls related to the roll represented by the test results; and
- review the MQC certificates and monitor that the certified roll properties meet the specifications.

20.8.2.3 Conformance Testing

The Resident Engineer shall obtain conformance samples (at the manufacturing facility or site) at the specified frequency and forward them to the Geosynthetics CQA Laboratory for testing to monitor conformance to both the Technical Specifications and the list of properties certified by the Manufacturer. The test procedures will be as indicated in Table 20-3. Where optional procedures are noted in the test method, the requirements of the Technical Specifications will prevail.

Table 20-3: Geomembrane conformance testing requirements

Test Name	Test Method	Frequency
Specific Gravity	ASTM D 792 Method A or ASTM D 1505	18 600 m^2
Thickness	ASTM D 5199	18 600 m^2
Tensile Strength at Yield	ASTM D 638	18 600 m^2
Tensile Strength at Break	ASTM D 638	18 600 m^2
Elongation at Yield	ASTM D 638	18 600 m^2
Elongation at Break	ASTM D 638	18 600 m^2
Carbon Black Content	ASTM D 1603	18 600 m^2
Carbon Black Dispersion	ASTM D 5596	18 600 m^2
Interface Shear Strength	ASTM D 5321	1 per project

Samples will be taken across the width of the roll and will not include the first linear 500mm of material. Unless otherwise specified, samples will be 500mm long by the roll width. The Resident Engineer will mark the machine direction on the samples with an arrow along with the date and roll number. The required minimum sampling frequencies are provided in Table 20-3.

The Resident Engineer will examine results from laboratory conformance testing and will report any non-conformance to the Construction Manager and the Geosynthetic Installer. The procedures prescribed in the Technical Specifications will be followed in the event of a failing conformance test.

20.8.3 Delivery

20.8.3.1 Transportation and Handling

The Resident Engineer will document that the transportation and handling does not pose a risk of damage to the geomembrane.

Upon delivery of the rolls of geomembrane, the Resident Engineer will document that the rolls are unloaded and stored on site as required by the Technical Specifications. Damage caused by unloading will be documented by the Resident Engineer and the damaged material shall not be installed.

20.8.3.2 Storage

The Geosynthetic Installer will be responsible for the storage of the geomembrane on site. The Contractor will provide storage space in a location (or several locations) such that on-site transportation and handling are optimized, if possible, to limit potential damage.

The Resident Engineer will document that storage of the geomembrane provides adequate protection against sources of damage.

20.8.4 Geomembrane Installation

20.8.4.1 Introduction

The Resident Engineer will document that the geomembrane installation is carried out in general accordance with the Drawings, Technical Specifications, and Manufacturer's recommendations.

20.8.4.2 Earthworks

Surface Preparation

The Resident Engineer will document that:

- The prepared subgrade meets the requirements of the Technical Specifications and has been approved; and
- Placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.
- The Geosynthetic Installer will certify in writing that the surface on which the geomembrane will be installed is acceptable. The Certificate of Acceptance, as presented in the Technical Specifications, will be signed by the Geosynthetic Installer and given to the Resident Engineer prior to commencement of geomembrane installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the Resident Engineer concurs with the Geosynthetic Installer, then the Resident Engineer shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the Resident Engineer will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

Geosynthetic Termination

The Resident Engineer will document that the geosynthetic terminations (Anchor Trench) have been constructed in general accordance with the Drawings. Backfilling above the terminations will be conducted in general accordance with the Technical Specifications.

20.8.4.3 Geomembrane Placement

Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field. It will be the responsibility of the Resident Engineer to document that each field panel is given an "identification code" (number or letter-number) consistent with the Panel Layout Drawing. This identification code will be agreed upon by the Construction Manager, Geosynthetic Installer and Resident Engineer. This field panel identification code will be as simple and logical as possible. Roll numbers established in the manufacturing plant must be traceable to the field panel identification code.

The Resident Engineer will establish documentation showing correspondence between roll numbers, and field panel identification codes. The field panel identification code will be used for all CQA records.

Field Panel Placement

Location

The Resident Engineer will document that field panels are installed at the location indicated in the Geosynthetic Installer's Panel Layout Drawing, as approved or modified by the Construction Manager.

Installation Schedule

Field panels may be installed using one of the following schedules:

- All field panels are placed prior to field seaming in order to protect the subgrade from erosion by rain;
- Field panels are placed one at a time and each field panel is seamed after its placement (in order to minimize the number of un-seamed field panels exposed to wind); and
- Any combination of the above.

If a decision is reached to place all field panels prior to field seaming, it is usually beneficial to begin at the high point area and proceed toward the low point with "shingle" overlaps to facilitate drainage in the event of precipitation. It is also usually beneficial to proceed in the direction of prevailing winds. Accordingly, an early decision regarding installation scheduling should be made if and only if weather conditions can be predicted with reasonable certainty. Otherwise, scheduling decisions must be made during installation, in general accordance with varying conditions. In any event, the Geosynthetic Installer is fully responsible for the decision made regarding placement procedures.

The Resident Engineer will evaluate every change in the schedule proposed by the Geosynthetic Installer and advise the Construction Manager on the acceptability of that change. The Resident Engineer will document that the condition of the subgrade soil has not changed detrimentally during installation.

The Resident Engineer will record the identification code, location, and date of installation of each field panel.

Weather Conditions

Geomembrane placement will not proceed unless otherwise authorized when the ambient temperature is below 5°C or above 50°C. In addition, wind speeds and direction will be monitored for potential impact to geosynthetic installation. Geomembrane placement will not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), and/or in an area of ponded water.

The Resident Engineer will document that the above conditions are fulfilled. Additionally, the Resident Engineer will document that the subgrade soil has not been damaged by weather conditions. The Geosynthetics Installer will inform the Construction Manager if the above conditions are not fulfilled.

Method of Placement

The Resident Engineer will document the following:

- Equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- The surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- Geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- Personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- The method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels); and
- Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent the uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels).

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

Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the Resident Engineer. Repairs will be made in general accordance with procedures described in Section 20.8.4.5.

20.8.4.4 Field Seaming

This section details CQA procedures to document that seams are properly constructed and tested in general accordance with the Manufacturer's specifications and industry standards.

Requirements of Personnel

All personnel performing seaming operations will be qualified by experience or by successfully passing seaming tests, as outlined in the Technical Specifications. The most experienced seamer, the "master seamer", will provide direct supervision over less experienced seamers.

The Geosynthetic Installer will provide the Construction Manager and the Resident Engineer with a list of proposed seaming personnel and their experience records. These documents will be reviewed by the Construction Manager and the Geosynthetics CQA Manager.

Seaming Equipment and Products

Approved processes for field seaming are fillet extrusion welding and double-track fusion welding.

Fillet Extrusion Process

The fillet extrusion-welding apparatus will be equipped with gauges giving the temperature in the apparatus.

The Geosynthetic Installer will provide documentation regarding the extrusion welding rod to the Resident Engineer, and will certify that the extrusion welding rod is compatible with the Technical Specification, and in any event, is comprised of the same resin as the geomembrane.

The Resident Engineer will log apparatus temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The Resident Engineer will document that:

- The Geosynthetic Installer maintains, on site, the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- Equipment used for seaming is not likely to damage the geomembrane;
- The extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- The electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- The geomembrane is protected from damage in heavily trafficked areas.

Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus will be equipped with gauges giving the applicable temperatures and pressures.

The Resident Engineer will log ambient, seaming apparatus and geomembrane surface temperatures as well as seaming apparatus speeds.

The Resident Engineer will also document that:

- The Geosynthetic Installer maintains on-site the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- Equipment used for seaming is not likely to damage the geomembrane;
- For cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- The electric generator is placed on a smooth cushioning base such that no damage occurs to the geomembrane from ground pressure or fuel leaks;
- A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- The geomembrane is protected from damage in heavily trafficked areas.

Seam Preparation

The Resident Engineer will document that:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material; and
- Seams are aligned with the fewest possible number of wrinkles and "fishmouths."

Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows unless authorized in writing by the Engineer:

- Seaming will only be approved between ambient temperatures of 5°C and 35°C.

If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 5°C or above 35°C, the Geosynthetic Installer will demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced within acceptable temperature, and that the overall quality of the geomembrane is not adversely affected.

The Resident Engineer will document that these seaming conditions are fulfilled and will advise the Geosynthetics Installer if they are not.

Overlapping and Temporary Bonding

The Resident Engineer will document that:

- The panels of geomembrane have a finished overlap of a minimum of 75mm for both extrusion and fusion welding;
- No solvent or adhesive bonding materials are used; and
- The procedures utilized to temporarily bond adjacent panels together do not damage the geomembrane.

The Resident Engineer will log appropriate temperatures and conditions, and will log and report.

Trial Seams

Trial seams shall be prepared with the procedures and dimensions as indicated in the Technical Specifications. The Resident Engineer will observe trial seam procedures and will document the results of trial seams on trial seam logs. Each trial seam samples will be assigned a number. The Resident Engineer will log the date, time, machine temperature(s), seaming unit identification, name of the seamer, and pass or fail description for each trial seam sample tested.

Separate trial seaming logs shall be maintained for fusion welded and extrusion welded trial seams.

General Seaming Procedure

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

- Fusion-welded seams are continuous, commencing at one end to the seam and ending at the opposite end.
- Cleaning, overlap, and shingling requirements shall be maintained.

- If seaming operations are carried out at night, adequate illumination will be provided at the Geosynthetic Installer's expense.
- Seaming will extend to the outside edge of panels to be placed in the anchor trench.

The Resident Engineer shall document geomembrane seaming operations on seaming logs. Seaming logs shall include, at a minimum:

Seam identifications (typically associated with panels being joined);

- Seam starting time and date;
- Seam ending time and date;
- Seam length;
- Identification of person performing seam; and
- Identification of seaming equipment.

Separate logs shall be maintained for fusion and extrusion welded seams. In addition, the Resident Engineer shall monitor during seaming that:

- Fusion-welded seams are continuous, commencing at one end of the seam and ending at the opposite end.
- Cleaning, overlap, and shingling requirements are maintained.

Non-destructive Seam Continuity Testing

Concept

The Geosynthetic Installer will non-destructively test field seams over their length using a vacuum test unit, air pressure test (for double fusion seams only), or other method approved by the Construction Manager. The purpose of nondestructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of field seaming.

The Resident Engineer will:

- Observe continuity testing;
- Record location, date, name of person conducting the test, and the results of tests; and
- Inform the Geosynthetic Installer of required repairs.

The Geosynthetic Installer will complete any required repairs in general accordance with Section 20.8.4.5.

The Resident Engineer will:

- Observe the repair and re-testing of the repair;
- Mark on the geomembrane that the repair has been made; and
- Document the results.

The following procedures will apply to locations where seams cannot be non-destructively tested:

All such seams will be cap-stripped with the same geomembrane:

- If the seam is accessible to testing equipment prior to final installation, the seam will be non-destructively tested prior to final installation.
- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations will be observed by the Resident Engineer and Geosynthetic Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test or observation will be recorded by the Resident Engineer.

Vacuum Testing

Vacuum testing shall be performed utilizing the equipment and procedures specified in the Technical Specifications. The Resident Engineer shall observe the vacuum testing procedures and document that they are performed in accordance with the Technical Specifications. The result of vacuum testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, the personnel performing the vacuum test and the result of the test (pass or fail), and the test date. Seams failing the vacuum test shall be repaired in accordance with the procedures listed in the Technical Specifications. The Resident Engineer shall document seam repairs in the seaming logs.

Air Pressure Testing

Air channel pressure testing shall be performed on double-track seams created with a fusion welding device, utilizing the equipment and procedures specified in the Technical Specifications. The Resident Engineer shall observe the air channel pressure testing procedures and document that they are performed in accordance with the Technical Specifications. The result of air channel pressure testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, personnel performing the air pressure test, the starting air pressure and time, the final air pressure and time, the drop in psi during the test, and the result of the test (pass or fail). Seams failing the air pressure test shall be repaired in accordance with the procedures listed in the Technical Specifications. The Resident Engineer shall document seam repairs in the seaming logs.

Destructive Testing

Concept

Destructive seam testing will be performed on site and at the independent CQA laboratory in general accordance with the Drawings and the Technical Specifications. Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

Location and Frequency

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

- The frequency of geomembrane seam testing is a minimum of one destructive sample per 150 m of weld. The minimum frequency is to be evaluated as an average taken throughout the entire facility.
- A minimum of one test per seaming machine over the duration of the project.
- Additional test locations may be selected during seaming at the Resident Engineer's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

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

Sampling Procedure

Samples will be marked by the Resident Engineer following the procedures listed in the Technical Specifications. Preliminary samples will be taken from either side of the marked sample and tested before obtaining the full sample per the requirements of the Technical Specifications. Samples shall be obtained by the Geosynthetic Installer. Samples shall be obtained as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material.

The Resident Engineer will:

- Observe sample cutting and monitor that corners are rounded;
- Assign a number to each sample, and mark it accordingly;
- Record sample location on the Panel Layout Drawing; and
- Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

Holes in the geomembrane resulting from destructive seam sampling will be immediately repaired in general accordance with repair procedures described in Section 20.8.4.5. The continuity of the new seams in the repaired area will be tested in general accordance with Section 20.8.4.4 – *Non-destructive Seam Continuity Testing*.

Size and Distribution of Samples

The destructive sample will be 0.3 m wide by 1.1 m long with the seam centered lengthwise.

The sample will be cut into three parts and distributed as follows:

- One portion, measuring 300 mm × 300 mm, to the Geosynthetic Installer for field testing;
- One portion, measuring 300 mm × 450 mm, for CQA Laboratory testing; and
- One portion, measuring 300 mm × 300 mm, to the Construction Manager for archive storage.

Final evaluation of the destructive sample sizes and distribution will be made at the Pre-Construction Meeting.

Field Testing

Field testing will be performed by the Geosynthetic Installer using a gauged tension-meter. Prior to field testing the Geosynthetic Installer shall submit a calibration certificate for gauge tension-meter to the Resident Engineer for review. Calibration must have been performed within one year of use on the current project. The destructive sample shall be tested according to the requirements of the Technical Specifications. The specimens shall not fail in the seam and shall meet the strength requirements outlined in the Technical Specifications. If any field test specimen fails, then the procedures outlined in Procedures for Destructive Test Failures of this section will be followed.

The Resident Engineer will witness field tests and mark samples and portions with their number. The Resident Engineer will also document the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description.

CQA Laboratory Testing

Destructive test samples will be packaged and shipped, if necessary, under the responsibility of the Resident Engineer in a manner that will not damage the test sample. The Construction Manager will be responsible for storing the archive samples. This procedure will be outlined at the Pre-construction Meeting. Samples will be tested by the CQA Laboratory. The CQA Laboratory will be selected by the Resident Engineer with the concurrence of the Engineer.

Testing will include "Bonded Seam Strength" and "Peel Adhesion." The minimum acceptable values to be obtained in these tests are given in the Technical Specifications. At least five specimens will be tested for each test method. Specimens will be selected alternately, by test, from the samples (i.e., peel and shear). A passing test will meet the minimum required values in at least four out of five specimens.

The CQA Laboratory will provide test results no more than 24 hours after they receive the samples. The Resident Engineer will review laboratory test results as soon as they become available, and make appropriate recommendations to the Construction Manager.

Geosynthetic Installer's Laboratory Testing

The Geosynthetic Installer's laboratory test results will be presented to the Construction Manager and the Resident Engineer for comments.

Procedures for Destructive Test Failure

The following procedures will apply whenever a sample fails a destructive test, whether that test conducted by the CQA Laboratory, the Geosynthetic Installer's laboratory, or by gauged tension-meter in the field.

The Geosynthetic Installer has two options:

- The Geosynthetic Installer can reconstruct the seam between two passed test locations.
- The Geosynthetic Installer can trace the welding path to an intermediate location at 3 m minimum from the point of the failed test in each direction and take a small sample for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

Acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. Repairs will be made in general accordance with Section 20.8.4.5.

The Resident Engineer will document actions taken in conjunction with destructive test failures.

20.8.4.5 Defects and Repairs

This section prescribes CQA activities to document that defects, tears, rips, punctures, damage, or failing seams shall be repaired.

Identification

Seams and non-seam areas of the geomembrane shall be examined by the Resident Engineer for identification of defects, holes, blisters, undispersed raw materials and signs of contamination by foreign

matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination.

Evaluation

Potentially flawed locations, both in seam and non-seam areas, shall be non-destructively tested using the methods described in Sub-section 20.8.4.4 under "Non-destructive Seam Continuity Testing" part, as appropriate. Each location that fails the nondestructive testing will be marked by the Resident Engineer and repaired by the Geosynthetic Installer. Work will not proceed with any materials that will cover locations which have been repaired until laboratory test results with passing values are available.

Repair Procedures

Portions of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be at the discretion of the Resident Engineer with input from the Construction Manager and Geosynthetic Installer.

The procedures available include:

- Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
- Grinding and re-welding, used to repair small sections of extruded seams;
- Spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws;
- Capping, used to repair large lengths of failed seams;
- Removing bad seam and replacing with a strip of new material welded into place (used with large lengths of fusion seams).

In addition, the following provisions will be satisfied:

- Surfaces of the geomembrane which are to be repaired will be abraded no more than 20 minutes prior to the repair;
- Surfaces must be clean 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 by the Resident Engineer with input from the Engineer and Geosynthetic Installer;
- Patches or caps will extend at least 150 mm beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 75 mm;
- Cuts and holes to be patched shall have rounded corners; and
- The geomembrane below large caps should be appropriately cut to avoid water or gas collection between the two sheets.

Verification of Repairs

The CQA Monitor shall monitor and document repairs. Records of repairs shall be maintained on repair logs.

Repair logs shall include, at a minimum:

- Panel containing repair and approximate location on panel;
- Approximate dimensions of repair;

- Repair type, i.e. fusion weld or extrusion weld
- Date of repair;
- Seamer making the repair; and
- Results of repair non-destructive testing (pass or fail).

Each repair will be non-destructively tested using the methods described herein, as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, per the requirements of the Technical Specifications. Failed tests shall be redone and re-tested until passing test results are observed.

Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane liner is completed) and prior to placing overlying materials, the Resident Engineer will observe the geomembrane wrinkles. The Resident Engineer will indicate to the Geosynthetic Installer which wrinkles should be cut and re-seamed. The seam thus produced will be tested like any other seam.

20.8.4.6 Lining System Acceptance

The Geosynthetic Installer and the Manufacturer(s) will retain all responsibility for the geosynthetic materials in the liner system until acceptance by the Construction Manager.

The geosynthetic liner system will be accepted by the Construction Manager when:

- The installation is finished;
- Verification of the adequacy of all seams and repairs, including associated testing, is complete;
- All documentation of installation is completed including the Resident Engineer's acceptance report and appropriate warranties; and
- CQA report, including "as built" drawing(s), sealed by a registered professional engineer has been received by the Construction Manager.

The Resident Engineer will document that installation was carried out in general accordance with the Technical Specifications for the project.

20.9 Geotextile

20.9.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the geotextile installation. The Resident Engineer will review the Drawings, and the Technical Specifications, and any approved addenda or changes.

20.9.2 Manufacturing

The Manufacturer will provide the Construction Manager with a list of guaranteed "minimum average roll value" properties (defined as the mean less two standard deviations), for each type of geotextile to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party employed by the Manufacturer that the materials actually delivered

have property “minimum average roll values” which meet or exceed all property values guaranteed for that type of geotextile.

The quality control certificates will include:

- Roll identification numbers; and
- Results of MQC testing.

The Manufacturer will provide, as a minimum, test results for the following:

- Mass per unit area;
- Grab strength;
- Tear strength;
- Puncture strength;
- Permittivity; and
- Apparent opening size.

MQC tests shall be performed at the frequency listed in the Technical Specifications. CQA tests on geotextile produced for the project shall be performed according to the test methods specified and frequencies presented in Table 20-4.

Table 20-4: Geotextile Conformance Testing Requirements

Test Name	Test Method	Min. Frequency
Mass per Unit Area	ASTM D 5261	2.5 ha
Grab Strength	ASTM D 4632	2.5 ha
Puncture Resistance	ASTM D 4833	2.5 ha
Permittivity	ASTM D 4491	2.5 ha
Apparent Opening Size	ASTM D 4751	2.5 ha

The Resident Engineer will examine Manufacturer certifications to evaluate that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

20.9.3 Labeling

The Manufacturer will identify all rolls of geotextile with the following:

- Manufacturer’s name;
- Product identification;
- Lot number;

- Roll number; and
- Roll dimensions.

The Resident Engineer will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

20.9.4 Shipment and Storage

During shipment and storage, the geotextile will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. To that effect, geotextile rolls will be shipped and stored in relatively opaque and watertight wrappings.

Protective wrappings will be removed less than one hour prior to unrolling the geotextile. After the wrapping has been removed, a geotextile will not be exposed to sunlight for more than 15 days, except for UV protection geotextile, unless otherwise specified and guaranteed by the Manufacturer.

The Resident Engineer will observe rolls upon delivery at the site and deviation from the above requirements will be reported to the Construction Manager.

20.9.5 Conformance Testing

20.9.5.1 Tests

Upon delivery of the rolls of geotextiles, the Resident Engineer will obtain conformance samples and forward to the Geosynthetics CQA Laboratory for testing to evaluate conformance to Technical Specifications. Required test and testing frequency for the geotextiles are presented in Table 20-4. These conformance tests will be performed in general accordance with the test methods specified in the Technical Specifications and will be documented by the Resident Engineer.

20.9.5.2 Sampling Procedures

Samples will be taken across the width of the roll and will not include the first 1 m. Samples will be 1 m long by the roll width, unless otherwise specified. The Resident Engineer will mark the machine direction on the samples with an arrow.

Samples will be taken at a rate as indicated in Table 20-4 for geotextiles, unless otherwise specified.

20.9.5.3 Test Results

The Resident Engineer will examine results from laboratory conformance testing and will report non-conformance with the Technical Specifications and this CQA Plan to the Construction Manager.

20.9.5.4 Conformance Sample Failure

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

- The Manufacturer will replace every roll of geotextile that is in non-conformance with the Technical Specifications with a roll(s) that meets Technical Specifications; or

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

20.9.6 Handling and Placement

The Contractor will handle all geotextiles in such a manner as to document they are not damaged in any way, and the following will be complied with:

- In the presence of wind, all geotextiles will be weighted with sandbags or the equivalent. Such sandbags will be installed during placement and will remain until replaced with cover material.
- Geotextiles will be cut using an approved geotextile cutter only. If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
- The Contractor will take all necessary precautions to prevent damage to underlying layers during placement of the geotextile.
- During placement of geotextiles, care will be taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the geotextile, generate clogging of drains or filters.

The Resident Engineer will note non-compliance and report it to the Construction Manager.

20.9.7 Seams and Overlaps

All geotextiles will be continuously sewn in accordance with Technical Specifications. Geotextiles will be overlapped 500 mm prior to seaming. No horizontal seams will be allowed on side slopes (i.e. seams will be along, not across, the slope).

Sewing will be done using polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile.

20.9.8 Repair

Holes or tears in the geotextile will be repaired as follows:

- On slopes: A patch made from the same geotextile will be double seamed into place. Should a tear exceed 10 percent of the width of the roll, that roll will be removed from the slope and replaced.
- Non-slopes: A patch made from the same geotextile will be spot-seamed in place with a minimum of 300 mm overlap in all directions.

Care will be taken to remove any soil or other material that may have penetrated the torn geotextile.

The Resident Engineer will observe any repair, note any non-compliance with the above requirements and report them to the Construction Manager.

20.9.9 Placement of Soil or Aggregate Materials

The Contractor will place all soil or aggregate materials located on top of a geotextile, in such a manner as to document:

- No damage of the geotextile;
- Minimal slippage of the geotextile on underlying layers; and
- No excess tensile stresses in the geotextile.

Non-compliance will be noted by the Resident Engineer and reported to the Construction Manager.

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Appendices – Chapter 20

Feasibility Study (Volume 2A)
Mmakau Coal (Pty) Ltd

December 2022

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Appendix 20.1

Parties Involved in the CQA Implementation

Company Name	Representatives Name	Email address	Contact number
Owner			
Construction Manager			
Design Engineer			
Resident Engineer			
Geosynthetics Manufacturer			
Geosynthetics Installer			
Contractor			
Independent CQA Laboratory			

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Appendix 20.2

Design Parameters

APPENDIX 20-2: DESIGN PARAMETERS

1. SITE CONDITIONS

1.1 Surface Water

- The nearest water course: Viskuile River, 2.5km
- Shortest distance to the 1:100-year flood line: 2.4km
- Regional Rainfall: 718mm/annum
- Regional evaporation: 1609mm/annum
- 1:50 year 24hr storm event: 118mm

1.2 Groundwater

- Depth to groundwater: 2.2m – 3.2m below NGL
- Aquifer classification: Two aquifers occur in the area, a) the upper weathered material, and b) the underlying competent and fractured rock material.

1.3 Geotechnical Profile

- Depth to pebble marker: between 0.4m and 0.6m
- Transported soil: The transported soil or hillwash horizon was present in all test pits to depths varying between 0.4m and 0.6m, with an average thickness of 0.5m. The composition of this horizon generally comprises loose to medium dense silty and clayey sand with moderate grading moduli. The weighted plasticity index of the samples ranges between 7% and 10%, these together with the low to moderate clay content of 13% to 21%, are indicative of a plastic material with a low potential expansiveness, according to the interpretation approach proposed by van der Merwe. The upper 0.3m of the hillwash contain abundant plant roots and have been extensively reworked in the crop field areas.
- Residual soil: The hillwash is underlain by residual shale in T13 and T16 which comprises silty clay with low grading moduli. The hillwash is underlain by slightly ferruginised residual sandstone in T14 which comprises silty and clayey sand with gravel. The hillwash is underlain by ferruginised residual shale in T15 which comprises a 700mm to 1.2m thick layer of stiff sandy and silty clay with ferricrete nodules with high grading moduli.
- Depth to hard rock: The bedrock generally occurs between depths of approximately 6.5m to 10m.
- Foundation rock description: Slightly weathered, medium hard and hard rock sandstone with some shale inter beds.
- Collapsible structure: Not applicable, there are no dolomitic soils underlying the MRF site.
- Seismicity: Not applicable, SANS 10160-2011 (Part 4) code describes the requirements for seismic design when a site is located in Zones I and II, but is silent on requirements when the site is located outside any of the identified seismic hazard zones. Since the site located outside the specified zones, it is apparent that there is no obligation to design for horizontal seismic acceleration for the site.

1.4 Topography

- Wall/ embankment side slopes: 1:2.5 (V:H)
- Minimum floor slope: 1.25%

2. MATERIAL PROPERTIES

2.1 Clay for Barrier Systems

- PI: 10 to 18
- Standard Proctor: Clay layer to be obtained from site excavations classified as SC or CL according to the Unified Classification System. The layer must be compacted to 100% Standard Proctor at maximum dry density.
- Percentage Clay: Between 9% and 42%
- Maximum particle size: 100% passing 13.5mm
- Permeability: 10^{-6} cm/s
- Minimum shear strength: Friction angle of 22° and cohesion of 0 kPa

2.2 Geomembrane

- Indicator parameters: Compliance with SANS 1526 (2015)
- Performance parameters: ≤ 3%. The use of 500mm thick sacrificial layer silty sand layer is expected to limit the maximum tensile strain in the geomembrane to ≤ 3%.

2.3 Liner Protection

- Description of soil:

0 – 500mm – Sacrificial layer of 500mm thickness consisting of fine to medium sandy or similar suitable material to be obtained from site excavations. The sacrificial layer is placed in two 250mm thick layers to cover the HDPE geo-membrane (GM), which will aid in protecting the GM from mechanical damage. It further protects the liner from UV radiation and thermal expansion whilst applying a confining stress to ensure intimate contact between the primary geo-membrane and the underlying clay layers and ensures that no folds are captured in the primary liner during installation.

500 – 1500mm – A subsoil cut-off drain shown in Figure 9-5 which includes a 160mm diameter Geopipe imbedded in 19mm clean stone and wrapped in Kaytech A5 non-woven geotextile (or similar). The subsoil drain will be spaced at approximately 15m centres to intercept and discharge seepage from the mine residue and discharge it to PCD A and will further reduce the hydraulic head across the liner.

500/1500mm – A robust double-sided textured 2mm thick HDPE geomembrane laid in direct contact with the clay layer.

500/1500 – A 300mm thick compacted clay layer obtained from site excavations classifying as SC or

800/1800mm – CL according to the Unified Classification System. The clay layer will be placed in two 150mm thick layers and compacted to 100% Standard Proctor at 0 – 2% of the optimum moisture content. The permeability of this layer must be lower than 1 x 10-6 cm/s.

800/1800 – 950/1950mm – A base preparation layer consisting of in-situ modification of the foundation by ripping, shaping and compaction to 95% Standard Proctor at OMC.

950 – 1250mm – Leakage detection finger drain spaced at approximately 45m centres, comprising filter elements similar to those proposed for the subsoil cut-off drain.

2.4 Waste (Coarse and fine residue material from coal mining operation)

- Waste type assessed as: Type 3 as per NEMWA R635 of 2013
- Material Strength Properties (density and strength): Density: Compacted Density (dry / bulk) – 1.5 t/m^3 to 1.6 t/m^3, Loose Density (dry / bulk) – 1.3 t/m^3 to 1.4 t/m^3, Fine Coal Slurry – Dry Density – 0.9 t/m^3.
- Degree of saturation: Coarse residue moisture of approximately 5%
- Permeability: 10^{-4} cm/s to 10^{-5} cm/s
- Estimating pollution period (years): 16 year LOM and 30 year post closure, 46 years in total.
- Maximum depth and rate of rise: 40m, rise of 8m.

3. SYSTEM PERFORMANCE CRITERIA

- Predicted mechanism of failure:
  - Global circular slip failure
  - Local circular slip failure
  - Global wedge failure
  - Local wedge failure
- Minimum factor of safety:
  - Global circular slip failure – 1.77
  - Local circular slip failure – 1.87
  - Global wedge failure – 2.09
  - Local wedge failure – 2.36
- Frequency of PCD overtopping: < than once in 50 years based on a dynamic daily water balance
- Action leakage rate: 100 l/ha/day to 400 l/ha/day
- Peak total tensile strain limitation: ≤ 3% The use of 500mm thick sacrificial layer silty sand is expected to limit the maximum tensile strain in the geomembrane to ≤ 3% (The maximum allowable strain on an HDPE geomembrane is 6% for long term field conditions with elevated temperature and chemical exposure).
- Elevated temperature and duration (°C and years): 35°C, 40 years
- Interface shear strength:
  - Local circular slip failure at the toe – FOS = 2.65 with filters working
  - Local wedge failure at the toe – FOS = 2.72 with filters working
- Wrinkles
  - Maximum height: 5cm
  - Maximum wrinkle length (with good quality control during installation as per CQA plan): 100m

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Appendix 20.3

Standard Specifications

APPENDIX 20.3 – STANDARD SPECIFICATIONS

Standard Specification	Description
SANS 1200 D	Earthworks
SANS 1526 (2015)	HDPE
SANS 10409 (2020)	Design, selection and installation of geomembranes
SANS 1083 (2014)	Aggregate
ASTM D 5747 and ASTM D 5721	Durability
ASTM D 7007 or D 8265	Form of electric leak location survey to be undertaken post placement of cover material
CPGL	Particular Specification Geosynthetic Liners

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