

MILLAR ROAD WASTE MANAGEMENT FACILITY

LEACHATE POND CONSTRUCTION SPECIFICATIONS

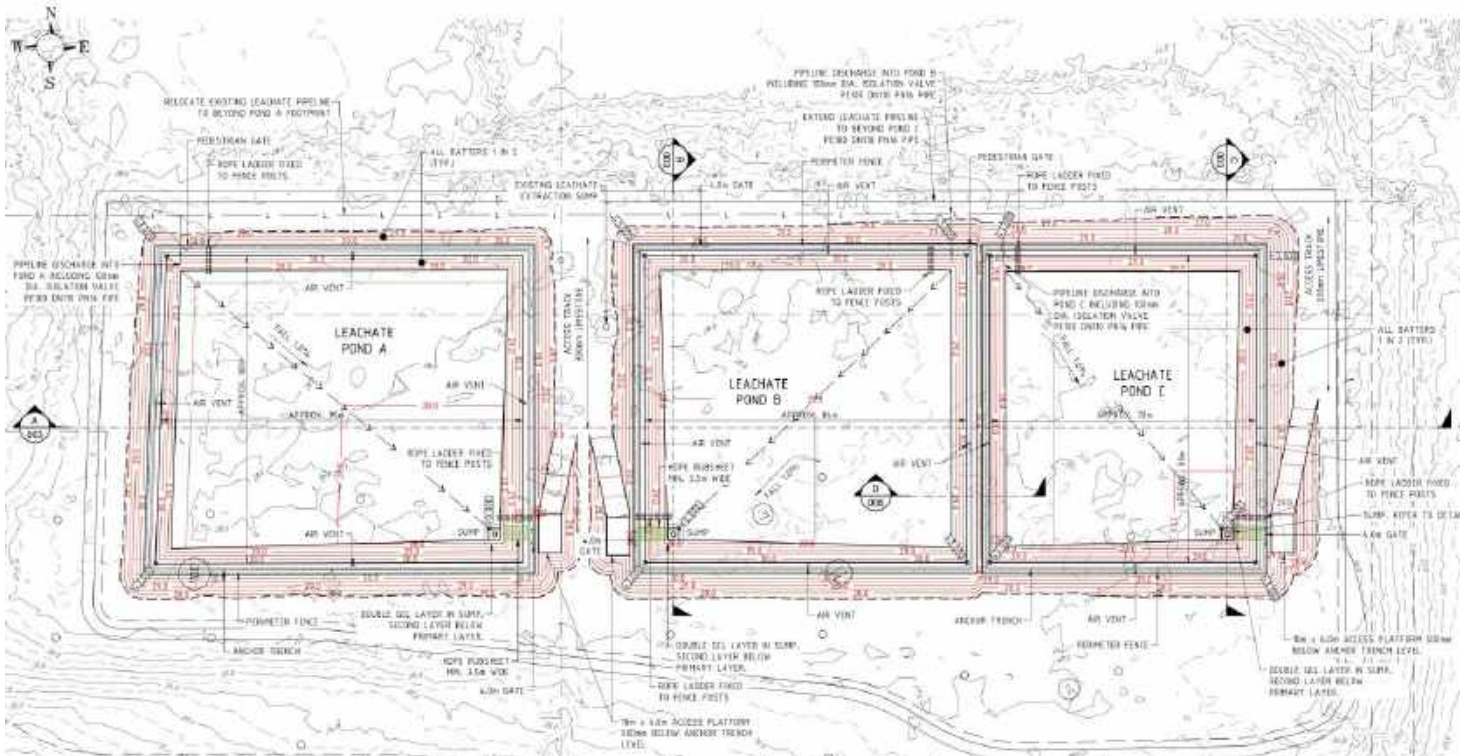


Image - Proposed Layout of Three New Leachate Ponds

Prepared for

CITY OF ROCKINGHAM

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1 Specifications

1.1 Description of Works

The Contract includes all management, operations, labour, plant, materials, supervision, survey and all else required for the construction and completion of the whole of the Works described in these Specifications and shown on the Drawings, and for complying with the Conditions of Contract, together with any additional Works or variations ordered by the Superintendent. The Contract also includes a Defects Liability Period as stated in the Annexure to the General Conditions of Contract.

The scope of Works includes:

- Survey and setting out;
- Vegetation clearing
- Minor Excavation to suit design layout;
- Fill placement to achieve design profile levels;
- Installation of synthetic liner system;
- Installation of leachate delivery pipeline;
- Installation of pond perimeter fencing and safety system;
- Such other Works as shown on the Drawings or as described in these Specifications
- Construction Quality Control testing and sampling; and,
- Provision of "As Constructed" information.

1.2 Works Not Included

The scope of the Works does not include:

- Supply of construction water; and,
- The supply of soil materials.

1.3 Principal

The Principal for the project will be the City of Rockingham.

1.4 Principal Supply Items

The Principal shall supply the following items:

- Water for construction; and,
- Soil fill materials for the works.



1.5 Quality Assurance, Inspection and Reporting

The Contractor shall undertake and cover the cost of all Construction Quality Control testing and measurement required in these Specifications to demonstrate that the specified standards of construction have been achieved. The exception being that the Principal shall pay for all Construction Quality Assurance (CQA) testing carried out by the Superintendent as stipulated in these Specifications. Any repeat Construction Quality Assurance testing due to material failure (non-conformance) or replacement shall be borne by the Contractor, other than for Principal Supply material defects. For the avoidance of doubt, Construction Quality Assurance testing refers to the testing of materials, where the Superintendent receives material samples and obtains independent testing thereof to confirm the materials conform to the Specifications.

The Contractor shall supply the GCL, bentonite powder, geomembrane and welding rods. This material will need to go through the necessary quality control process in order to confirm its suitability and acceptability for the Works prior to the material being incorporated into the Works. Replacement material will need to go through the necessary quality control process in order to confirm its suitability and acceptability prior to the Contractor installing it in the Works.

The Principal shall appoint and pay for the following:

- * Superintendent to manage the project on its behalf;
- * A Geotechnical Engineer (Earthworks Inspector) to inspect, approve and report on all aspects of the earthworks in accordance with AS 3798-2007, *Guidelines of Earthworks for Commercial and Residential Development* and issuing a final CQA report to the Superintendent documenting the quality of the constructed earthworks; and,
- * A CQA Consultant, who may also be the Geotechnical Engineer. The duties of the CQA Consultant will include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on interpretation of the Specifications and issuing a final CQA Validation Report to the Superintendent documenting the quality of the constructed Works.

Within these Specifications, the Superintendent is nominated as the responsible party to undertake all Construction Quality Assurance testing, inspections, approvals and reporting as the Superintendent has the management responsibility for these aspects of the Works; however, the Superintendent will allocate some of these activities to either the Geotechnical Engineer or the CQA Consultant, depending on the task to be undertaken.

The Contractor is to provide the necessary assistance to the Geotechnical Engineer and the CQA Consultant as if it was dealing with the Superintendent.

If there is any confusion as to which party the Contractor should be dealing with, the Contractor is to always default back to the Superintendent for guidance.

The Geotechnical Engineer and the CQA Consultant are not entitled to provide the Contractor with any advice on construction or design matters. The Contractor is not to rely on any construction or design advice from either the Geotechnical Engineer or the CQA Consultant. Any related queries are to be directed to the Superintendent.



1.6 Contract Limits

The Works limits shall be in accordance with the Drawings.

1.7 Areas Available to the Contractor

On written request, the Superintendent will allocate work, storage and laydown areas for use by the Contractor.

1.8 Contractor's Facilities

The Contractor shall be responsible for the supply of its own Site services, including power, potable water, wastewater and communications. The proposed details of the Contractor's power, potable water and sanitation arrangements shall be submitted to the Superintendent for approval and shall be maintained throughout the Works.

The Contractor shall be responsible for the maintenance and watering of the access roads within the Works area as defined by the Drawings and workplaces.

Waste and refuse of all sorts will be regularly and satisfactorily removed. On completion of the Works all sanitary facilities will be removed, the ground thoroughly disinfected and the Site restored to its original condition.

1.9 Pollution and Spillage

Without limiting the Contractor's obligations under the Contract, it shall be the Contractor's responsibility to:

- Investigate and comply with all applicable laws;
- Investigate and comply with Regulations and Rules relating to pollution and contamination with particular regard to the water discharging off the Site; and,
- Limit airborne dust and noise, which could cause a hazard or nuisance to other persons or property. The Superintendent may require the Contractor to take additional steps to reduce the dust hazard and any steps taken shall be at the Contractor's cost.

During construction and commissioning, spillage of any type whatsoever, including fabricating and hydraulic oils, fuel and any other material, shall be immediately removed and disposed of, and the area cleaned as directed by the Superintendent.

1.10 Hours of Site Work

The Superintendent's hours of work on the project will normally be:

- Monday to Friday (inclusive) 0700 to 1700.

Should the Contractor require to work outside these hours, the Contractor shall submit a request in writing to the Superintendent, stating the reason and working hours required, 24 hours in advance and, in any event, not later than noon. The Superintendent will not refuse a reasonable request.

For the purpose of variations and extensions of time to Contract shall consist of 10 hours per working day. The Contract Price shall be deemed to include all additional costs incurred resulting from compliance with industrial awards.



The Contractor will be required to work outside normal working hours to attend to emergency situations or as directed by the Superintendent to attend to items within the scope of Works.

Any variation to the above will be at the discretion of the Superintendent and subject to prior written approval. Refusal to vary or extend the hours of work will not be grounds for an extension of time or a direction to accelerate the Works.

For the purpose of Liquidated Damages assessment, a day will mean any 24 consecutive hour day including Saturdays, Sundays and statutory holidays.

1.11 Site Meetings/Briefings

The Contractor must attend Site meetings/briefings with the Principal and/or Superintendent at times which will be notified to the Contractor. The Contractor must ensure the attendance of all sub-contractors directly concerned with the Works in progress at the time. The Superintendent will keep records of these meetings and these records will form part of the Contract Documentation. No claims for costs borne by the Contractor in attending Site meetings will be accepted.

1.12 Remedial Work During Defects Liability Period

The Contractor shall be responsible to perform work during the Defects Liability Period in accordance with the General Conditions of Contract.

1.13 Water for use in the Works

Water for moisture conditioning of compacted fill and dust suppression will be available on Site via a standpipe arrangement within 1 km of the Works area.

The Principal will provide all necessary water supply and equipment to extract and transfer the water from the source to the Contractor's collection vehicle.

1.14 Setting Out and Measurement of Quantities

The Contractor shall be responsible for setting out the Works and to confirm survey control to the Superintendent to the grades and levels shown on the Drawings.

The Contractor shall be responsible for the measurement of quantities under the Contract. Quantities shall be determined by a competent person by field survey, and outcomes of the survey and quantity calculations shall be forwarded to the Superintendent for verification.

The Contractor is to use a suitably qualified surveyor for all survey work. A suitably qualified surveyor includes:

- A qualified and experienced surveyor able to be a fulltime member of the Institution of Mining and Engineering Surveyors Australia; or,
- A surveyor licensed under the WA Licensing Board; or,
- A surveyor that has undertaken similar works and at the same level of responsibility for a minimum of five years and has a proven track-record of reliable survey works.

Quantities to be measured for variations must be measured in accordance with AS 1181.



1.15 Weather

The Contractor takes all risk associated with delays related to bad weather. The Contractor is to allow within its program of Works for anticipated delays as a result of bad weather. There will be no extension of time or cost variation as a result of bad weather.

This Clause does not release the Contractor from any obligation to weatherproof and protect the Works, and to remove water from the Works as soon as is practical during and after inclement weather.

1.16 Protection from Weather

The Contractor must, at the Contractor's own expense, provide all plant, materials and labour necessary to protect the Works from damage by inclement weather.

The Contractor must prevent, insofar as is reasonably possible any materials entering any gully, manhole or pipe, and must remove from the drainage system any materials from any source which may be deposited in the drainage system by any agency up to the date of Practical Completion.

1.17 Dust and Wind-Blown Materials Control

The Contractor shall be responsible for the effective control and suppression of all dust and windborne material emanating from the Site as a result of the Works throughout the period of the Works on Site.

Dust management is a critical environmental emissions aspect on site. The Contractor is to ensure that all construction related activities are carried out in order to minimise dust generation. The Contractor is to adequately wet down all haulage roads to limit dust generation. Should the use of a water cart not be sufficient to adequately manage dust emissions, then the Contractor is to implement other, acceptable dust management measures to decrease dust generation. In the event that the Contractor is unable to adequately control dust during construction, the dust related activities are to be ceased until adequate dust management can be undertaken or the ambient weather conditions improve.

The Contractor is to be aware that the Principal has a comprehensive Dust Management Plan for the overall site. The Contractor is to ensure compliance with this Plan at all times.

1.18 Liaison with Others

During the course of the Works, the Contractor will need to interact with other works being carried out on Site. It shall be the Contractor's responsibility to closely liaise with others on Site to ensure Works are completed in accordance with the requirements of the Specification, Drawings and the Superintendent's directions and instructions.

1.19 Provision for Traffic

When Works are proceeding adjacent to or on any existing access track or haul road, the Contractor shall notify the Superintendent and any other company using that access track or haul road seven days in advance of the date that such Works are due to commence and the proposed duration of such Works and take all steps necessary during the execution of such Works to ensure that disruption to normal traffic is minimised.



1.20 Demobilisation

Prior to the issue of a Certificate of Practical Completion, the Contractor shall, unless otherwise agreed in writing by the Superintendent, have removed all goods and temporary Works from the Site.

All Contractor lay down areas shall be cleaned and graded by the Contractor to the satisfaction of the Superintendent.

1.21 Vegetation and Site Clearing

The Site is an existing waste management facility.

There is no native vegetation clearing associated with the construction works. There is however vegetation (weeds) clearing associated with the preparation of the Works area.



1.22 Earthworks

1.22.1 Introduction

The Works covered by this Section include, but are not necessarily limited to, the following:

- The setting out of the Works to the lines and levels shown on the Drawings;
- Removal of unsuitable subgrade material and disposal to spoil;
- Excavation within the Works area;
- Working around existing gas extraction pipework;
- Grading and compaction of pond footprint, the leachate extraction sump and pond perimeter bunds;
- Excavation and haulage of fill, moisture conditioning, placement and compaction to the required grades and levels;
- Surface preparation of completed earthworks prior to liner installation;
- Excavation and backfill of liner anchor trenches for liner installation;
- Formation of access ramps;
- Construction Quality Control testing and sampling; and,
- Control and diversion of surface water and run-off from within the Works area.

1.22.2 Earthworks Inspection

It is a requirement of the environmental approval for the landfill development that all significant earthworks be accompanied by Level 1 geotechnical testing as set out in Appendix B of AS 3798-2007, *Guidelines of Earthworks for Commercial and Residential Development*. To achieve this, the Principal will appoint and pay for an independent Geotechnical Engineer (Earthworks Inspector) to inspect, approve and report on all aspects of the earthworks. This is to include:

- Approval of the suitability of the fill material used;
- Approval of the suitability of excavations to remove soft and unsuitable material from the pond base and side slopes;
- Approval of the compaction method used;
- Inspection of all fill placement and compaction activities;
- Inspection of all Construction Quality Control testing and sampling (arranged and paid for by the Contractor);
- Assessment of the Construction Quality Control testing results and As-Constructed survey;
- Approval of the earthworks quality and shape;
- Compilation of an earthworks quality assurance report for submission to the Environmental Regulator; and,
- Any other activities that are deemed necessary to ensure that appropriate earthworks standard of workmanship and quality of Works is achieved.

Earthworks not included in the Level 1 geotechnical inspection include:

- General excavation down to the final design profile.

If the Contractor over-excavates any areas, the backfill of the over-excavated area will be subject to Level 1 inspection and testing. If the Principal incurs additional Construction Quality Assurance costs associated with the Level 1 geotechnical inspection and testing of the over-excavation, the Contractor will be liable for these additional costs.



Where the Specifications refer to inspection, approval or other activities relating to the Superintendent, some of these actions may be carried out by the Geotechnical Engineer, on behalf of the Superintendent.

1.22.3 Applicable Documents

All Works shall be carried out in accordance with the latest editions of all and any specifications, guidelines and standards referenced with the Contract.

1.22.4 Definitions

For all purposes of this Section, the words and phrases listed below shall have the meanings herein ascribed to them:

- "Modified Maximum Dry Density" (MMDD) As determined in accordance with AS 1289.5.2.1-2003.

1.22.5 Handover

On handover of the Site to the Contractor, the Contractor is to undertake a detailed baseline survey of the Works area. As a minimum, the surface shall be surveyed about the perimeter of the Works area and on a maximum 20 m grid and include all changes in grade within the perimeter. The survey is to identify all necessary details to accurately determine the surface topography for the purposes of measuring construction qualities. The results of the survey shall be provided to the Superintendent prior to any Works commencing. This baseline survey will be compared to the Principal's baseline survey (which may have been undertaken prior to Site handover) and the handover baseline survey profile will be agreed between the Parties.

In the event of there being water ponding on the surface, the base survey is to take into account the volume of water and this is to be considered when using the base survey to calculate Works related quantities. The mechanism of accounting for the volume of ponded water is to be agreed between the Parties.

This agreed handover baseline survey will then be used for calculating quantities of Works undertaken throughout the project.

No Works shall be undertaken in any area until the handover baseline survey has been agreed between the Parties and without the written confirmation of the Superintendent.

1.22.6 Excavation

1.22.6.1 *General*

The Contractor shall carry out all earthworks excavation to the extent shown on the Drawings or directed by the Superintendent. The Contractor is responsible for assessing the soil types on Site and selecting suitable plant and equipment for undertaking excavation Works.

There is only minor excavation associated with the excavation of the pond sump.

All completed earthworks are to be inspected and approved by the Superintendent.

1.22.6.2 Excavated Material

Suitable excavated material is to be used as fill material.

The Superintendent will determine the suitability of the excavated material for use as fill.

1.22.7 Fill Materials

1.22.7.1 General

The Contractor shall carry out all earthworks fill to the extent shown on the Drawings or as directed by the Superintendent. The Contractor is responsible for assessing the fill requirements and selecting suitable plant and equipment for undertaking required Works.

All fill material must be approved for use by the Superintendent, who may reject unsuitable material.

1.22.7.2 Material

Select fill material shall comprise naturally occurring sandy soil sourced on-site from the excavation Works or within 1 km of the Works area. The material is to be free of debris and deleterious material and with a maximum particle dimension no larger than 200 mm for bulk fill and 40 mm for fill within 500 mm of the lined surface. The suitability of the fill material will be determined by the Superintendent prior to incorporation into the Works.

1.22.7.3 Unsuitable Material

The term "unsuitable material" shall apply to large items and weak deposits and organic material, which, because of its inherent nature, cannot be satisfactorily reconditioned and is not suitable as a foundation, bedding or backfill material. Unsuitable material shall be removed within the limits specified by the Superintendent using whatever equipment is required.

All material that is deemed unsuitable by the Superintendent to be used as fill will be stockpiled, as directed by the Superintendent, within 1 km of the Works area.

1.22.8 Sub-Grade Preparation

On completion of excavation, all standing water shall be drained or pumped away before sub-grade preparation can commence.

The sub-grade of the cell shall be graded to maintain a uniform fall to the lowest part of the pond. On the completion of grading, the area shall be thoroughly wetted and rolled with a minimum four passes of a smooth drum vibrating roller.

The completed surface shall be surveyed about the perimeter of the area and on a maximum 20 m grid within the perimeter. The results of the survey shall be provided to the Superintendent prior to inspecting the sub-grade to confirm the Works meets the specified requirements.

No fill shall be placed in any area without the written approval of the Superintendent.



1.22.9 Fill Placement and Compaction

1.22.9.1 Inspection

Before fill is placed in any area, the Superintendent shall be notified in writing 24 hours prior to Works commencing. The Superintendent may inspect the area to confirm the Works conforms to the Specifications. Any area of ground that has been disturbed to such a depth that it cannot be compacted to the required standard in conjunction with the first layer of fill, shall be worked and compacted to the required standards before routine fill operations begin.

1.22.9.2 General Placement and Compaction Standards

Fill shall be placed, levelled, moisture conditioned to +/- 2 % of optimum, and compacted to not less than 95% of the Modified Maximum Dry Density (MMDD) determined in accordance with AS 1289.5.2.1. As a minimum standard, all areas of fill are to be compacted in layers of no greater than 300 mm or less than 100 mm. Where less than 100 mm is required to be worked, the underlying material shall be scarified to such a depth that the resulting thickness of the layer to the Works is greater than 100 mm.

Each layer worked shall be generally parallel to the finished surface and shall, where practicable, extend to the full width of the embankment/fill in that particular level. The Contractor shall at all times prevent ponding of water on the embankment/fill.

The Contractor may propose an alternative fill placement and compaction methodology to the Superintendent for review and acceptance; however, the Contractor is to ensure that any proposed methodology is able to achieve a minimum compaction density of 95% of the Modified Maximum Dry Density (MMDD) determined in accordance with AS 1289.5.2.1.

1.22.9.3 Final Surface Preparation

The complete surface of the base and batters of the landfill that are to be covered with environmental barrier liner material (GCL and HDPE) are to be steel drum rolled to provide a smooth surface on which to place the liner material. The surface, prior to rolling is to have been finished to have no irregularities in excess of 40 mm over 3 m. In addition, following rolling, the surface is to have no irregularities in excess of 10 mm deep over a straightedge length of 20 mm (small sharp irregularities).

Prior to the deployment of the GCL, the surface is to be inspected to confirm there are no excessive irregularities, depressions or obstructions that may affect the integrity of the synthetic liner.

The Contractor is to be aware that the sloping portions of the landfill cell are relatively steep (maximum 1 vertical in 2 horizontal) and extreme care is to be taken when working in these areas. In addition, when placing liner material, the Contractor is to ensure that the prepared surface below the liner is not damaged by the liner installation equipment. Any damage to the surface is to be repaired prior to the liner being installed.

1.22.9.4 Compaction Testing

The Contractor shall arrange for the testing and sampling of compacted fill. Fill operations shall be interrupted as necessary to allow the recovery of samples or to carry out control tests on the fill.



All materials testing and density testing shall be undertaken by a laboratory that is NATA accredited for those tests being undertaken. Testing will be used to confirm specified moisture conditions and standards of compaction are achieved. All testing shall be undertaken in accordance with the appropriate sections of AS1289 – Methods for Testing Soils for Engineering Purposes.

Testing and sampling will be undertaken at regular intervals by the Contractor or its nominated representatives. The construction programming and Contract Sum shall include allowances for taking and testing samples and time delays while samples are being collected and tested.

No additional payment will be made for any completed Works requiring removal and/or repair as a result of any tests organised by the Superintendent.

Inspection and testing shall be carried out in accordance with the requirements of this Specification.

The frequency of field density testing during these Works shall not be less than the following:

- One test per 500 m³ distributed evenly throughout the full depth and area;
- One test per layer per material type per 2,500 m², distributed evenly over the surface of the layer;
- One test per layer or per 300 mm thickness per 150 m length constructed horizontal layer;
- Three tests per visit when material is placed in horizontal layers; or,
- Whichever frequency is greater of the above or alternative frequencies that may be agreed with the Superintendent.

Field density tests shall be determined by Nuclear Densometer methods (AS1289.5.8.1) in association with modified compaction (AS1289.5.2.1).

Compaction shall be carried out in accordance with the Assigned Values Method, as defined by AS1289.5.4.2.

If any areas of the Works are found to be non-compliant with the compaction requirements of this Specification, they shall be re-worked (if necessary), re-compacted and re-tested for compliance.

1.22.9.5 *Dimensions and Tolerances*

The finished levels of fill shall be within -25 mm and +25 mm of the design levels along the top of the pond perimeter bund and within -50 mm and +50 mm of the design levels in the pond side walls and base.

The fill surface shall be inspected to ensure accuracy and any irregularities in excess of 40 mm when tested with a 3 m long straight edge shall be corrected prior to the surface treatment being applied.

1.22.9.6 *Control of Water*

During excavation and construction, all areas of earthworks shall be kept free of water by temporary drains or other means. Surface water shall be prevented from flowing onto the excavations or fill areas by the construction of diversion drains or other suitable mechanisms before any other excavation commences. Excavation and fill areas shall always be graded to facilitate surface drainage and any loose material compacted to prevent absorption.



Particular care shall be taken to ensure that surface water does not reach embankments or fill material that has yet to be compacted.

1.22.9.7 *Surface Confirmation*

The completed surface shall be surveyed by the Contractor on a maximum 20 m grid to confirm the accuracy of construction and to include the levels along the position of the leachate sump and the perimeter bunds. The results of the survey shall be provided to the Superintendent prior to inspecting the completed surface to confirm the Works meets the specified requirements.

No liner installation shall be carried out in any area without the written approval of the Superintendent.

1.22.9.8 *Dust Management*

Dust management is a critical environmental emissions aspect on site. The Contractor is to ensure that all construction related activities are carried out in order to minimise dust generation. The Contractor is to adequately wet down all haulage roads to limit dust generation. Should the use of a water cart not be sufficient to adequately manage dust emissions, then the Contractor is to implement other, acceptable dust management measures to decrease dust generation. In the event that the Contractor is unable to adequately control dust during construction, the dust related activities are to be ceased until adequate dust management can be undertaken or the ambient weather conditions improve.

The Contractor is to be aware that the Principal has a comprehensive Dust Management Plan for the overall site. The Contractor is to ensure compliance with this Plan at all times.

1.22.9.9 *Clean-up*

On completion of the Works the Site shall be cleared of all materials and debris. Any damage shall be made good, and the Site restored to a neat and tidy condition. All Works areas shall be smoothed and graded conforming to the natural appearance of the landscape.



1.23 Installation of Geosynthetic Clay Liner

1.23.1 General

The construction Works incorporates the use of a standard GCL product overlaid by an HDPE liner.

1.23.1.1 *Exposure to Sodium Bentonite*

It is noted that sodium bentonite is classified as hazardous for both State and Federal legislation, largely to eliminate any silica and cristobalite risk. Key points are as follows:

- The exposure risk of sodium bentonites and any crystalline silica (quartz and cristobalite) contained within, is based on dust concentrations in the air, and the length of exposure.
- There is no Short-term exposure limit set, it is all 8-hour Time-Weighted Average (TWA). Hence, a maximum average exposure level over an 8 hr/5 day week is considered, the TWA is 0.1 mg/m³ averaged over the 40 hr week.
- This means that exposure levels are considered over a time period, and for GCLs this time period should only apply to people working with GCL's for an extended period.
- The exposure risk for cutting samples or handling onsite is short term, but this fundamentally means that it is easier to analyse the risk, but also easier to adopt full protection controls and not rely on engineering controls.
- **The advice is always to wear suitable PPE as defined in the material manufacturer's Safety Data Sheet (SDS) or in the relevant Australian Standard, wherever the risk of dust generation is observed.**

From a construction point of view, there is an OH&S risk with the exposure of sodium bentonite from the GCL, particularly around the risk of crystalline silica exposure when the GCL is cut for sampling and whilst being installed; consequently, the Contractor is to ensure that the following activities are carried out:

- All parties, including the Contractor's staff, lining sub-contractor and any other relevant sub-contractors, Superintendent, CQA Consultant, the Principal's staff and anyone who may come in contact with the GCL are to be made aware of the risks associated with exposure to sodium bentonite;
- The Contractor (who is accountable for the sampling and installation of the GCL) is to develop a safety plan for the handling, sampling and installation of GCL and bentonite powder or paste, including detailed procedures that will be undertaken to mitigate exposure to dust from the GCL (eg masks or respirators). The safety plan is to be developed in accordance with the manufacturer's SDS and industry best practise.
- The safety plan is to be provided to the Principal, Superintendent and all relevant parties prior to the sampling, installation or testing of the GCL and that procedures mentioned in the plan are being adhered to.
- This risk is to be discussed in toolbox talks at the start and throughout the construction program, when GCL is being handled on site.



1.23.1.2 GCL Installation Sub-Contractor

The Contractor shall only engage the specialist liner sub-contractor, which may also be the main Contractor to install the GCL that was accepted by the Principal at the time of Contract award. Any change to the approved liner sub-contractor must be approved in writing by the Superintendent prior to any lining Works being undertaken on Site.

The GCL shall be installed in all locations as indicated in the Drawings. It is noted that there is also a double layer of GCL in the landfill leachate sump (as indicated in the Drawings).

The primary function of the lining system is to prevent leachate from leaking from the impoundment and subsequently entering and polluting the groundwater in the local area. Stringent quality assurance standards shall be maintained throughout the Works to ensure the integrity of the lining system.

Stringent quality assurance standards shall be maintained throughout the Contract to ensure the integrity of the lining system.

The Contractor shall provide all materials, supervision, labour and equipment for the installation of the GCL in accordance with the Specifications and Drawings.

Prior to installation, all GCL to be incorporated in the Works is to have been approved in writing by the Superintendent.

1.23.1.3 Submittals

Submittal Documentation

The Contractor is to submit the following to the Superintendent for review and approval, within a reasonable time to expedite installation of the GCL. This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- If any proposed change in liner sub-contractor from what was approved at Contract award, documentation of the liner sub-contractor and installer's qualifications:
 - Submit proposed sub-contractor relevant company experience;
 - Submit resumes or qualifications of the proposed Field Installation Supervisor, Master Installer and Installer to be assigned to this project; and,
- Liner installation Quality Control Program.

Panel Layout Drawings

Submit copies of panel layout drawings for the Superintendent's approval within a reasonable time so as not to delay the start of GCL installation. Panel layout drawings shall show the proposed panel layout. Panels shall generally follow the direction of the slope. Where possible, roll-end joints shall not occur on the side slope. Where this is unavoidable, the join is to include a minimum 1.5 m overlap, as indicated in the Drawings. The joins between GCL panels on the side slope and the base shall be located on the base at a distance of at least 1.5 m from the slope toe.

Placement of GCL will not be allowed to proceed until the Superintendent has received and approved the panel layout drawings.



Additional Submittals (In-Progress and at Completion):

This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- Daily written acceptance of subgrade surface;
- Daily field installation reports; and,
- Installation record drawing.

1.23.1.4 Quality Control

Installer's Qualifications

Installation and joining of the GCL must be undertaken by GCL installers with extensive experience in installing and joining the same type of GCL being installed and using the same joining procedure to be used on Site.

Installation shall be performed under the direction of a Field Installation Supervisor who shall be responsible throughout the GCL installation, for GCL panel layout, joining, patching, repairs and all other activities of the liner sub-contractor. The Field Installation Supervisor shall have installed or supervised the installation and joining of a minimum of 10 projects involving a total of 500,000 m² of GCL of the type specified or similar product.

Joining shall be performed under the direction of a Master Installer (who may also be the Field Installation Supervisor) who has joined a minimum of 300,000 m² of GCL of the type specified or similar product, using the same type of joining to be used in the current project. The Field Installation Supervisor and/or Master Installer shall be present whenever installation and joining is performed.

Installation and joining shall be performed by an Installer who has installed and joined a minimum of 100,000 m² of GCL of the type specified or similar product, using the same type of joining to be used in the current project.

All joining, patching, other operations shall be performed by qualified installers employed by the GCL sub-contractor.

Independent CQA Consultant

The Principal will appoint an independent CQA Consultant with experience and knowledgeable of GCL and joining performance characteristics to verify that the Works have been carried out in accordance with the Specifications.

The duties of the CQA Consultant include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on installation, repair, and covering of the GCL lining system in accordance with the Specifications and Drawings and issuing a final CQA Validation Report to the Principal documenting the quality of the constructed facility.

The cost associated with the appointment of the CQA Consultant will be covered by the Principal.

The Contractor is to provide the necessary assistance, advanced notification of lining activities and access to all Works area to the CQA Consultant to enable the full inspection of the Works.



1.23.1.5 Delivery, Storage and Handling

Each roll of GCL delivered to the Site will be labeled by the manufacturer. The label will be firmly affixed and shall clearly state the following:

- Manufacturer's name;
- Product identification (material type);
- Date of manufacture;
- Batch number;
- Roll number;
- Roll length;
- Roll weight;
- Roll width; and,
- Label with handling guidelines.

The GCL rolls shall be delivered to the Site by the Contractor. The material will be handled and stored in such manner that no damage occurs to the GCL or its protective wrapping. The GCL rolls shall be wrapped with heavy duty weatherproof wrapping to protect the material from moisture uptake.

Rolls with damaged wrapping shall be pointed out to the Superintendent who will inspect to assess the extent of hydration of the liner. GCL rolls or portions of rolls with moisture content equal or above 40% by weight (ASTM D5993) may be rejected, as instructed by the Superintendent. GCL rolls with damaged wrapping and moisture content lower than 40% shall be re-wrapped and sealed.

A dedicated area shall be used for the storage of all GCL material delivered to Site. The material shall be stored and handled as follows:

- In its original, unopened packaging or resealed following the removal of samples from the roll;
- Away from high traffic areas, but sufficiently close to the active Works area to minimise handling;
- On a level, dry, well-drained and stable area;
- Not more than three (3) rolls high;
- Protected from precipitation, chemicals, excessive heat, ultraviolet (UV) radiation, standing water, vandalism and animals;
- Blocks provided to prevent sliding or rolling of stacks;
- All roll labeling shall be clearly visible;
- Handling of GCL rolls is to be via the use of a spreader bar or stinger bar (a bar protruding from the front end of a forklift or other equipment). The bar must be capable of supporting the full weight of the GCL roll without significant bending; and,
- Under no circumstances may the rolls be dragged, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle.

Any damaged material shall be assessed by the Superintendent and if deemed necessary, rejected and the Contractor advised to immediately remove the material from Site.



1.23.1.6 GCL Pre-Construction Meeting

A GCL Pre-Construction Meeting (and simultaneously the Geomembrane Pre-Construction Meeting) shall be held at the Site prior to installation of the GCL. As a minimum, the meeting shall be attended by the GCL Field Installation Supervisor, the Superintendent, the CQA Consultant and the Contractor.

Topics for this meeting shall include:

- Responsibilities of each party;
- Lines of authority and communication;
- Resolution of any project document ambiguity;
- Project QA/QC plan;
- Methods for documenting, reporting and distributing documents and reports;
- Procedures for packaging and storing archive samples;
- Review of time schedule for all installation and inspection;
- Weather limitations;
- Defining acceptable subgrade, GCL, or ambient moisture and temperature conditions for working during liner installation;
- Subgrade conditions, dewatering responsibilities and subgrade maintenance plan;
- Deployment techniques including allowable subgrade for the liner installation and in particular, working on the side slopes;
- Consideration of how subsequent liner material will be placed on top of the GCL ideally without driving on the lined surface, including the ongoing repair of the earthworks surface ahead of liner installation;
- Covering of the GCL – normal practice and in the event of rain;
- Measurement and payment schedules; and,
- Health and safety, including protection from exposure to sodium bentonite powder.

The Superintendent will take minutes of the meeting and the minutes shall be transmitted to all Parties.

1.23.2 Product

1.23.2.1 Manufacturing Quality Control

The test methods and frequencies used by the manufacturer for quality control/quality assurance of the GCL prior to delivery shall be in accordance with Section 1.23.5 - Table 1.

The manufacturer's GCL quality control certifications, including results of quality control testing of the products, must be supplied to the Superintendent to verify that the materials supplied for the project are in compliance with all product and/or project Specifications. The certification shall be signed by a responsible party employed by the manufacturer, such as the QAIQC Manager, Production Manager or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.

1.23.2.2 Minimum Requirements for GCL

The GCL shall be a reinforced, multi-layered system comprising two layers of geotextiles encapsulating a layer of dry bentonite.



The bentonite and GCL will meet the property requirements as shown in Section 1.23.5 - Table 1.

Bentonite used for overlapping shall comply with the same specifications as the bentonite used in the GCL delivered to the Site (same rule applies for sealing penetrations and repairs).

Material Construction Quality Assurance testing by the Superintendent will be conducted in accordance with the project Specifications and CQA Plan.

1.23.2.3 *Manufacturing Quality Control Documentation*

MQC documentation from the manufacturer of the GCL supplied must be submitted for approval by Superintendent. Submissions shall include:

- Location and date of manufacture;
- Lot number, roll number, length and width;
- Bentonite manufacturer quality documentation for the particular lot of clay used in the production of the rolls delivered;
- MSDA or bentonite used during manufacture;
- Geotextile manufacturer quality control documentation for the particular lots of geotextiles used in the production of the rolls delivered;
- Cross-referencing list delineating the corresponding geotextile and bentonite lots for the materials used in the production of the rolls delivered;
- QC program laboratory certified reports in accordance with Section 1.23.5 – Table 1; and,
- The manufacturer's approved QA stamp and the technician's signature.

1.23.2.4 *Acceptance by Superintendent*

No materials will be accepted for delivery to Site or for progress payment unless all necessary manufacturer's quality assurance/quality control certification, including results of quality control testing has been provided to the Superintendent. All such data shall be supplied in sufficient time such that no delay shall be caused to the project program. Failure to provide the required certifications and test data and any resultant delay will not be grounds for an extension of time or removal of any commercial penalties that accompany the Contract.

In addition, no material will be accepted for progress payment until the necessary Construction Quality Assurance testing has demonstrated that the material delivered to site is of the acceptable standard.



1.23.3 Installation

1.23.3.1 Project Conditions

GCL shall not be installed in the presence of standing water, while precipitation is occurring or during excessive winds.

1.23.3.2 Surface Preparation

The surface to be lined shall be uniform and free of all sharp or angular objects that may damage the GCL prior to installation of the liner and the quality of the surface maintained until liner has been installed.

The Contractor, liner sub-contractor and Superintendent shall inspect the surface to be covered with the GCL on each day's operations prior to placement of GCL to verify suitability.

The liner sub-contractor shall provide daily written acceptance to the Superintendent for the surface to be covered by the GCL installation, to ensure surface suitability.

All subgrade surface damage caused by construction equipment and deemed unsuitable for GCL deployment shall be repaired by the Contractor prior to placement of the GCL. All repairs require the approval of the Superintendent and the liner sub-contractor.

1.23.3.3 GCL Placement

No GCL shall be deployed until the applicable certifications and quality control certificates are submitted to, and approved by the Superintendent. Should GCL material be deployed prior to approval by the Superintendent it will be at the sole risk of the Contractor. If the material does not meet project Specifications, it shall be removed from the Works area at no cost to the Principal.

The GCL shall be installed such that the panels are anchored at the crest of the slope and are continuous down side slopes, with no roll end joins on the slopes. Where possible, the panels shall also be continuous across the base. The arrangement of the GCL panels shall be according to a predetermined layout plan to minimise the amount of end overlaps.

The panels shall be laid in roof tile effect to allow continuous flow of water/leachate in the downward slope direction.

The GCL shall be installed to the limits shown on the Drawings and essentially as shown on approved panel layout drawings.

The GCL shall only be placed on adequately prepared surfaces that have been approved by the Superintendent.

Appropriate lifting equipment is to be used to ensure safe and efficient material placement and any damage to the subbase by lifting equipment shall be repaired prior to the laying of any GCL.

Installation of the GCL shall not result in scratching, scoring, tearing or otherwise damaging of the material.



The GCL sub-contractor and Superintendent shall inspect the surface of each roll of material as it is being deployed or after deployment, to verify that the material is free from visual defects such as tears, punctures, abrasions, thin spots or other faults in the material. If damages are identified, they are to be repaired or replaced according to these Specifications or as directed by the Superintendent.

Ideally no vehicular traffic shall travel on the liner material; however, this is not always practical. If vehicle access is required over the placed liner material, it is to be kept to an absolute minimum, vehicles are to travel in straight lines and not turn on the liner material, be approved by the Superintendent and no rough treaded tyres are to be used, only "turf tyres" (low tread tyres) with low ground contact pressure to protect the underlying subbase.

Prior to installation, the Contractor is to provide a method statement on how it is proposed to install the subsequent HDPE layer without any, ideally without driving on the lined surface. This method statement must be provided within a reasonable time so as not to delay the installation of the liner material.

GCL placement shall not be carried out during rainfall events, on a wet subbase, if moisture prevents proper surface preparation, panel placement or panel joining. Moisture limitations shall be defined in the pre-construction meeting.

Damaged panels or portions of the damaged panels, which have been rejected, shall be marked and removal from the Works area recorded.

The GCL shall not be allowed to "bridge over" voids or low areas in the subgrade. In these areas, the GCL shall be placed to allow the GCL to rest in intimate contact with the subbase. **Special attention to this aspect is to be paid when laying liner material in the leachate sump.**

Wrinkles caused by panel placement shall be minimised. In the event that wrinkles occur in the GCL or where wrinkles extend to the edge of the roll due to manufacturing tolerances, they will need to be removed prior to installation of subsequent layers.

Considerations on Site Geometry: In general, joins shall be oriented parallel to the line of the maximum slope. In corners and odd shaped geometric locations, the total length of joins shall be minimised. Joins shall not be located at low points in the subgrade unless geometry requires joins at such locations and if approved by the Superintendent.

Overlap joins between panels shall be formed by overlapping the panels and sealed by manufactured edge treatment, bentonite powder or paste. The overlap zone shall be kept clean and shall not be contaminated with loose soil or other debris. There shall be no folds or wrinkles in the overlap zone and no traffic or walking shall occur on the completed overlap. The minimum longitudinal overlap shall be 300 mm and the minimum roll-end overlap shall be 500 mm on the base and 1.5 m on the slope. Additional bentonite is to be applied between the sheets at all roll end joins at 1 kg/m² for bentonite paste or 250g/m² for bentonite powder, as indicated in the drawings.

Bentonite used for overlapping shall comply with the same specifications as the bentonite used in the GCL delivered to the Site (same rule applies for repairs).



Particular care shall be taken to avoid contaminating the upper surface of the GCL with bentonite powder. The presence of loose bentonite may affect welding of overlying geomembrane and may also influence interface friction.

GCL installed on slopes is to be installed in accordance with the detail in the Drawings, with no roll end joins on the slopes.

The GCL shall be covered by the geomembrane liner as soon as practical to prevent water damage, but at least by the end of each working day. No GCL is to be left uncovered overnight.

In the event of any water damage, the Superintendent will inspect the material to assess the extent of hydration of the liner. Areas of GCL with moisture content equal or above 40% by weight (ASTM D5993) may be rejected, as instructed by the Superintendent. Areas suspected of being over hydrated may be sampled and tested to confirm suitability, with costs borne by the Contractor; however, time constrains may impact the ability to test the hydrated material.

The liner sub-contractor shall surcharge load all lining material during construction with appropriate material (i.e. sandbags or approved equivalent) to ensure the liner is protected from wind uplift and displacement, including down-slope creep. The frequency and spacing of the sandbag shall be as required based on Site conditions and lining sub-contractor's experience/recommendation. The sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the liner. The sandbags shall be filled with material that does not pose a risk of damage to the geosynthetics. The sandbags must be removed prior to placement of subsequent layers of synthetic liner material.

To prevent the GCL from creeping down-slope, it may be necessary to partially backfill the base of the anchor trench to pin the GCL in position while subsequent layers are installed.

All material offcuts shall be removed from the Works area and not simply left under the GCL liner.

1.23.3.4 Joining Procedures

Joining procedures are to be as per the material Manufacture's installation instructions, with the following minimum overlaps:

- Longitudinal joins – 300 mm
- Roll-end joins:
 - On landfill base – 0.5 m; and,
 - On landfill side slope – 1.5 m.

1.23.3.5 Field Quality Control

Daily Field Installation Reports

At the beginning of each day's Works, the liner sub-contractor shall provide the Superintendent with daily reports for all Works accomplished on the previous Works day. Reports shall include the following:

- Total amount and location of GCL placed; and,
- Drawings of the previous day's installed GCL showing panel numbers.



1.23.3.6 Defects and Damage

The Superintendent shall inspect the GCL as it is rolled out on the surface to be lined. The Superintendent shall be responsible for the acceptance or rejection of GCL being incorporated into the Works, be it a function of manufacture or installation of the GCL.

Manufacturing defects are areas where the geotextile is not continuous and/or areas where the bentonite in the GCL is missing. If a roll is suspected to be of inferior quality the Superintendent may take samples to assess its conformance with the Specifications. All testing is to be carried out in accordance with the appropriate standards and by a NATA accredited laboratory. Construction Quality Assurance testing results will determine the adequacy of the GCL.

Material replacement as a result of identified defects or damage shall be carried out by the Contractor. The Contractor will be liable for the costs associated with the replacement of all defective liner materials. The Contractor will be liable for the costs associated with the replacement of all damaged liner material, including being liable for all CQA testing costs as a result of replacing damaged liner material.

1.23.3.7 Repair

If the GCL has been damaged during installation, it can be repaired by patching a new piece of GCL of the same material type and thickness extending a minimum of 500 mm on the base and 1.5 m on the side slope beyond the damaged area in each direction. The patched area must be augmented with bentonite powder or paste as per normal joining requirements.

1.23.3.8 Liner Acceptance

GCL liner will be accepted by the Superintendent when:

- The entire installation is finished, or an agreed-upon subsection of the installation is finished;
- All liner sub-contractor's QC documentation is completed, submitted to and approved by the Superintendent; and,
- All CQA testing on the installed material has been completed and approved by the Superintendent.

1.23.3.9 Disposal of Scrap Materials

On completion of installation, the liner sub-contractor shall dispose of all waste and scrap material in a location approved by the Superintendent, remove equipment used in connection with the Works herein, and shall leave the Site in a neat acceptable manner. No scrap material shall be allowed to remain on the GCL surface.

1.23.4 Materials Properties and Testing Scope

1.23.4.1 General

These Specifications set forth a set of minimum physical, mechanical and chemical properties that must be met, or exceeded by the GCL being manufactured. In a few cases a range is specified.

In the context of quality systems and management, these Specifications represents manufacturing quality control (MQC).

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

1.23.4.2 Definitions

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

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

1.23.4.3 Manufacturing Specifications and Quality Control

The quality of the GCL shall be in accordance with the requirements of the Geosynthetic Research Institute (GRI) — GCL3. The minimum specifications for quality GCL products are contained in GRI Test Method GCL3 Standard Specification for “*Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCL’s)*”. The GRI specifications set forth a set of minimum physical and mechanical properties that must be met or exceeded by the GCL being manufactured.

In addition to the above, the bentonite Specifications in Section 1.23.5 – Table 1 shall be verified every 50 tonnes of the product.

A statement on the origin of the bentonite must be included, as well as certified copies of the quality control certificates issued by the bentonite supplier and reports on the tests conducted by the manufacturer to verify the quality of the bentonite used to manufacture the GCL rolls assigned to the project.

The geotextile components of the GCL must also have been through a QC program. The manufacturer’s geotextile QC program shall be available for auditing.

1.23.4.4 Physical and Mechanical Property Requirements

The GCL shall conform to the test property requirements prescribed in Section 1.23.5 – Table 1.

The properties of the GCL shall be tested at the minimum frequency shown in Section 1.23.5 - Table 1. If the specific manufacturer’s quality control guide is more stringent and is certified accordingly, it must be followed in like manner.



1.23.4.5 Workmanship and Appearance

The GCL shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the GCL.

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

1.23.4.6 MQC Sampling

Sampling shall be in accordance with the specific test methods listed in Section 1.23.5 - Table 1. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

The number of tests shall be in accordance with the appropriate test methods listed in Section 1.23.5 - Table 1.

The average of the test results shall be calculated per the particular standard cited and compared to the minimum value listed in these tables; hence, the values listed are the minimum average values and are designated as "min. ave."; the exception being permeability, which is measured against the maximum average.

1.23.4.7 MQC Retest and Rejection

If the results of any test do not conform to the requirements of these Specifications, retesting to determine conformance or rejection shall be carried out in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

1.23.4.8 Packaging and Marketing

The GCL shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery.

The roll cores shall be sufficiently strong to ensure that they do not deflect by more than half their diameter during transit and handling.

1.23.4.9 Certification

A manufacturer's certification that the material was manufactured and tested in accordance with the Specifications, together with a report of the test results shall be furnished at the time of shipment.

1.23.4.10 Construction Quality Assurance Testing

The Contractor shall provide material samples to the CQA Consultant to test the rolls delivered to Site to demonstrate that the rolls meet the requirements of the Specifications. The test frequency shall be as set out in Section 1.23.5 - Table 1.

The Superintendent will arrange for independent Construction Quality Assurance testing of the material. The Superintendent shall arrange for samples to be recovered from the rolls delivered to Site and tested at an independent NATA accredited laboratory. The results from the independent laboratory shall take precedence over the test results provided by the manufacturer of the material. The Construction Quality Assurance testing shall be at the Principal's cost.



There is the option for the sampling of the materials for Construction Quality Assurance testing to occur either at the point of manufacturer, at the supplier's local warehouse or after delivery to the site.

If sampling for CQA testing is proposed to be undertaken prior to material delivery to site, then sampling and testing is to be undertaken in accordance with the CQA Consultant's instruction to ensure the appropriate chain of custody controls applied for the samples between recovery and testing and chain of custody controls between manufacture and use in the works onsite.

The Superintendent will arrange/coordinate for independent Construction Quality Assurance testing of the material. In order to achieve this:

- The Superintendent will determine the location of where the samples are to be received, either at the point of manufacture, supplier's warehouse or on Site;
- The timing of when the sampling will occur is to be coordinated by the Superintendent, between all Parties, to ensure the most efficient sampling process and handover of the samples. This will either be during or immediately after manufacture or as soon as is reasonable following delivery to the supplier's local warehouse or to Site;
- The CQA Consultant or nominated representative (for non-local sampling) will be present at the point of sampling to monitor the sampling procedure and to receive the samples;
- The Contractor is responsible for providing all samples, as required, from the rolls of liner material that will or have been delivered to Site and handing the samples to the CQA Consultant; and,
- The CQA Consultant will arrange for the delivery and testing of the samples to be carried out at an independent NATA accredited laboratory.

The CQA results from the independent laboratory shall take precedence over the test results provided by the manufacturer of the material. The Construction Quality Assurance testing shall be at the Principal's cost.

Any non-conformance in the delivered materials as identified by the Construction Quality Assurance testing shall be addressed by the Contractor and thereafter, if the Superintendent rejects the material, the Contractor shall replace the non-conforming material with conforming material. Again, the new delivery of material will be subject to Construction Quality Assurance testing to demonstrate its conformance with the Specifications. Any replacement of non-conforming material and subsequent Construction Quality Assurance testing carried out by the Superintendent will be at the Contractor's cost.

The material delivered to Site shall meet the Specifications relative to the independent laboratory test results, for the material to be considered for incorporation into the Works.

Section 1.23.6 - Table 2 sets out the minimum Construction Quality Assurance testing that will be carried out by the Superintendent.



1.23.5 GCL Material Specification

All GCL material use shall be reinforced and comprised of both woven and non-woven geotextile fully needle punch and heat bonded together to contain the bentonite powder.

The GCL shall have the minimum material Specifications as set out in Table 1:

Table 1 - GCL Material Specification

Property	Test	Frequency	Value
Montmorillonite content	XRD (X-ray diffraction) Quantitative Mineralogy Analysis	50 tonnes of GCL	> 70 wt%
Carbonate content (1)		50 tonnes of GCL	1 - 2 wt%
Bentonite form		50 tonnes of GCL	Natural Na-bentonite or >80 wt% Sodium as activated bentonite
Particle size	AS 1289-3.6.2	50 tonnes of GCL	Powdered (e.g. 80% passing 75 micron sieve) or Granulated (e.g. < 1% passing 75 micron)
Cation exchange capacity	Methylene Blue Method	50 tonnes of GCL	≥ 70 meq/100 g (or cmol/kg)
Free Swell (bentonite) (min. ave.)	ASTM D5890	50 tonnes of GCL	≥ 24 mL/2g
Moisture Content (bentonite) (min. ave.) (2)	ASTM D5993	4,000 m ²	≤ 25% at Manufacture ≤ 35% Site Samples
Fluid Loss (bentonite) (min. ave.) (2)	ASTM D5891	50 tonnes of GCL	≤ 18 ml
Top Geotextile Mass (min. ave.) (3)	ASTM D5261	20,000 m ²	≥ 200 g/m ² non-woven
Mass per unit area of GCL (min. ave.) (4)	ASTM D5993	4,000 m ²	≥ 4,000 g/m ²
Mass per unit area of Bentonite (min. ave.) (4)	ASTM D5993	4,000 m ²	≥ 3,700 g/m ²
Mass per unit area of Bentonite in overlaps (min. ave.) (4)	ASTM D5993	4,000 m ²	≥ 3,950 g/m ² (3,700 g/m ² + 250 g/m ²)
Bottom Geotextile Mass (min. ave.)	ASTM D5261	20,000 m ²	≥ 200 g/m ² woven/non-woven
Elongation (MD) (min. ave.)	ASTM D4632	20,000 m ²	≥ 10%



Property	Test	Frequency	Value
Tensile Strength (min. ave.)	ASTM D6768	20,000 m ²	≥ 4 kN/m
Peel Strength (min. ave.)	ASTM D6496	4,000 m ²	≥ 360 N/m
Permeability (min. ave.) (2)	ASTM D5887	25,000 m ²	≤ 5 x 10 ⁻¹¹ m/s

- (1) Carbonate here implies calcite, calcium carbonate or other soluble or partially soluble carbonate minerals
- (2) These values are maximum (all others are minimum).
- (3) For both cap and carrier fabrics for non-woven reinforced GCL's; one, or the other, must contain a scrim component of mass ≥ 100 g/m² for dimensional stability. This only applies to GM/GCL composites, which are exposed to the atmosphere for several months or longer so as to mitigate panel separation.
- (4) Mass of the GCL and bentonite is measured after oven drying per the stated test method.

The GCL rolls shall include edge treatment on both longitudinal sides of the GCL with 250 dry grams added bentonite per metre length of overlap included in the outer 300 mm strip of the roll. The rolls shall also include edge markings to indicate a minimum 300 mm overlap for panels.



1.23.6 GCL CQA Testing

The GCL shall undergo the minimum CQA testing as set out in Table 2:

Table 2 - GCL CQA Testing

Item	Property	Standard	Frequency
Construction Quality Assurance testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Composite layer Thickness (dry)	ASTM D1777	1 sample every 3 rd roll
	Mass per unit area of bentonite component of GCL	ASTM D5993	1 sample per 2,500 m ²
	Mass per unit area of GCL	ASTM D5993	1 sample per 1,000 m ²
	Mass per unit area of Bentonite in overlaps	ASTM D5993	1 sample every 3 rd roll
	Montmorillonite content	XRD (X-ray diffraction) Quantitative Mineralogy Analysis	1 sample per 10,000 m ²
	Cation exchange capacity of bentonite	Methylene blue method	1 sample per 1,500 m ²
	Moisture content (bentonite)	ASTM D5993 AS1289.2.1.1	1 sample per 2,500 m ²
	Free Swell (bentonite)	ASTM D5890	1 sample per 1,500 m ²
	Water absorption	ASTM D5891	1 sample per 1,500 m ²
	Peel strength	ASTM D6496	1 sample every 3 rd roll
	Tensile strength	ASTM D6768	1 sample per 10,000 m ²
	Index flux	ASTM 5887	1 sample per 10,000 m ²
	Permeability	ASTM 5887	1 sample per 10,000 m ²
Visual inspection of GCL	Colour, needle punching, presence of needles or broken needles, and sewing density or other faults in the material.	N/A	Every roll during placement
Thickness of GCL (i.e. uniformity of bentonite distribution) and apparent variations in the as placed moisture distribution.	On-Site	N/A	Each roll during placement. If thickness appears to be variable a check of the variability of the mass per unit area shall be conducted



Note:

1. All Construction Quality Assurance tests must be reviewed, accepted, and reported by the Superintendent before deployment of the GCL.
2. All testing must be performed on samples taken from the GCL delivered to Site or at the supplier's/manufacturer's premises under the Superintendent's inspection or delegated authority.
3. All laboratory tests must be performed in an independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state-of-the-art practice and/or to account for the criticality of the application (i.e to account for the importance of the GCL for the stability of Works).



1.24 Installation of Geomembrane

1.24.1 General

The construction Works incorporates the use of a smooth/textured HDPE product installed on top of a GCL liner, with the textured side down.

1.24.1.1 *Geomembrane Sub-Contractor*

The Contractor shall only engage the specialist liner sub-contractor, which may be the main Contractor to install the geomembrane that was accepted by the Principal at the time of award of Contract. Any change to the liner sub-contractor must be approved in writing by the Superintendent prior to any lining Works being undertaken on Site.

Geomembrane shall be installed in all locations as indicated in the Drawings.

The primary function of the lining system is to prevent leachate from leaking from the impoundment and subsequently entering and polluting the groundwater in the local area.

Stringent quality assurance standards shall be maintained throughout the Works to ensure the integrity of the lining system.

The Contractor shall provide all materials, supervision, labour and equipment for the installation of the geomembrane in accordance with the Specifications and Drawings.

Prior to installation, all geomembrane to be incorporated in the Works is to have been approved in writing by the Superintendent.

1.24.1.2 *Submittals*

Submittal Documentation

The Contractor is to submit the following to the Superintendent for review and approval, within a reasonable time to expedite shipment or installation of the geomembrane. This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- If any proposed change in liner sub-contractor from what was approved at Contract award, documentation of the liner sub-contractor and installer's qualifications:
 - Submit proposed sub-contractor relevant company experience; and,
 - Submit resumes or qualifications of the proposed Field Installation Supervisor, Master Installer and Installer to be assigned to this project; and,
- Liner sub-contractor Quality Control Program.

Panel Layout Drawings

Submit copies of panel layout drawings for the Superintendent's approval within a reasonable time so as not to delay the start of geomembrane installation. Panel layout drawings shall show the proposed panel layout identifying seams and details. Seams shall generally follow the direction of the slope. Butt seams or roll-end seams shall not occur on a slope. The connecting seam between geomembranes on the slope and the base shall be located in the base at a distance of at least 1.5 m from the slope toe or valley drain and also 1 m from any join in the GCL below.



All primary welds used to connect panel end to sheets shall form T-joints (tees). These T-connections must be a distance of at least 0.5 m apart. The welding seams of the geomembrane cannot cross (no cruciform connections).

Placement of geomembrane will not be allowed to proceed until the Superintendent has received and approved the panel layout drawings.

Additional Submittals (In-Progress and at Completion):

For convenience, the relevant Sections have been highlighted; however, these may not necessarily be the only references to submittal documentation required. This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- Geomembrane installation warranty;
- Daily written acceptance of substrate surface;
- Prequalification test seam samples;
- Field seam non-destructive test results;
- Field seam destructive test results;
- Daily field installation reports; and,
- Installation record drawing.

1.24.1.3 Quality Control

Manufacturer's Qualifications

The manufacturer of geomembrane of the type specified or similar product shall have at least five years' experience in the manufacture of such geomembrane. In addition, the geomembrane manufacturer shall have manufactured at least 1,000,000 m² of the specified type of geomembrane or similar product during the last five years.

Installer's Qualifications

Installation and seaming of the geomembrane must be undertaken by geomembrane installers with extensive experience in seaming the same type of geomembrane being installed and using the same seaming procedure to be used on Site.

Installation shall be performed under the direction of a Field Installation Supervisor who shall be responsible throughout the geomembrane installation, for geomembrane panel layout, seaming, patching, testing, repairs and all other activities of geomembrane installation. The Field Installation Supervisor shall have installed or supervised the installation and seaming of a minimum of 10 projects involving a total of 500,000 m² of geomembrane of the type specified or similar product.

Seaming shall be performed under the direction of a Master Seamer (who may also be the Field Installation Supervisor) who has seamed a minimum of 300,000 m² of geomembrane of the type specified or similar product, using the same type of seaming apparatus to be used in the current project. The Field Installation Supervisor and/or Master Seamer shall be present whenever seaming is performed.

Seaming shall be performed by an Installer who has seamed a minimum of 100,000 m² of geomembrane of the type specified or similar product, using the same type of seaming apparatus to be used in the current project.



All seaming, patching, other welding operations and testing shall be performed by qualified technicians employed by the geomembrane liner sub-contractor.

Independent CQA Consultant

The Principal will appoint an independent CQA Consultant with experience and knowledgeable of geomembrane and seam performance characteristics to verify that the Works have been carried out in accordance with the Specifications.

The duties of the CQA Consultant include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on installation, repair, and covering of the geomembrane lining system in accordance with the Specifications and Drawings and issuing a final CQA Validation Report to the Principal documenting the quality of the constructed facility.

The cost associated with the appointment of the CQA Consultant will be covered by the Principal.

The Contractor is to provide the necessary assistance, advanced notification of lining activities and access to all Works area to the CQA Consultant to enable the full inspection of the Works.

1.24.1.4 Delivery, Storage and Handling

Each roll of geomembrane delivered to the Site will be labeled by the manufacturer. The label shall be firmly affixed and shall clearly state the following:

- Manufacturer's name;
- Product identification (material type);
- Material thickness;
- Roll number;
- Roll length;
- Roll weight;
- Roll width;
- Reference number to raw material batch and laboratory certified reports; and,
- Manufacturer's approved QA stamp and the technician's signature. The technician's signature may be omitted from each roll label, but then must be included on each of the manufacturer's test certificates associated with each roll.

A dedicated area shall be used for the storage of all geomembrane material delivered to Site. The material shall be stored as follows:

- The geomembrane shall be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions;
- Away from high traffic areas, but sufficiently close to the active Works area to minimise handling;
- Elevated aboveground on a level, dry, well-drained and stable area. Should timber pallets be used, they must be inspected and free of nails/pins prior to roll placement;
- Not more than three rolls high;
- Protected from stormwater runoff, standing water, chemicals, excessive heat, vandalism and animals;
- Blocks provided to prevent sliding or rolling of stacks;
- All roll labeling shall be clearly visible;



- Handling of geomembrane rolls is to be via the use of a spreader bar or stinger bar (a bar protruding from the front end of a forklift or other equipment). The bar must be capable of supporting the full weight of the geomembrane roll without significant bending; and,
- Under no circumstances may the rolls be dragged, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle.

Any damaged material shall be assessed by the Superintendent and if deemed necessary, rejected and the Contractor advised to immediately remove the material from the Works area.

1.24.1.5 Geomembrane Pre-Construction Meeting

A Geomembrane Pre-Construction Meeting (and simultaneously the GCL Pre-Construction Meeting) shall be held at the Site prior to installation of the geomembrane. As a minimum, the meeting shall be attended by the geomembrane Field Installation Supervisor, the Superintendent, the CQA Consultant and the Contractor.

Topics for this meeting shall include:

- Responsibilities of each party;
- Lines of authority and communication;
- Resolution of any project document ambiguity;
- Project QA/QC plan;
- Methods for documenting, reporting and distributing documents and reports;
- Procedures for packaging and storing archive samples;
- Review of time schedule for all installation and testing;
- Review of panel layout and numbering systems for panels and seams including details for marking on geomembrane;
- Procedures and responsibilities for preparation and submission of As-Constructed panel and seam drawings;
- Temperature and weather limitations. Installation procedures for adverse weather conditions and temperature conditions for working during liner installation;
- Defining acceptable GCL moisture content prior to over-laying with geomembrane;
- GCL/subgrade conditions, dewatering responsibilities and GCL/subgrade maintenance plan;
- Deployment techniques, placement of geomembrane on top of GCL with the geomembrane textured side down, and in particular, working on the side slopes;
- Consideration of how subsequent liner material will be placed on top of the geomembrane, again, with particular focus on working on the side slopes;
- Plan for controlling expansion/contraction and wrinkling of the geomembrane;
- Covering of the geomembrane and drainage material placement;
- Measurement and payment schedules; and,
- Health and safety.

The Superintendent will take minutes of the meeting and the minutes shall be transmitted to all Parties.



1.24.1.6 Geomembrane Installation Warranty

The geomembrane liner sub-contractor shall guarantee the geomembrane installation against defects in the installation and workmanship for 1 year commencing with the date of final acceptance by the Superintendent.

1.24.2 Products

1.24.2.1 Manufacturing Quality Control Documentation

The test methods and frequencies used by the manufacturer for quality control/quality assurance of the geomembrane prior to delivery shall be in accordance with Section 1.24.5 - Table 3.

The manufacturer's geomembrane quality control certifications, including results of quality control testing of the products, must be supplied to the Superintendent to verify that the materials supplied for the project are in compliance with all product and/or project Specifications. The certification shall be signed by a responsible party employed by the manufacturer, such as the QAIQC Manager, Production Manager or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.

The Manufacturer will provide Certification that the geomembrane and welding rod supplied for the project have the same base resin and material properties.

1.24.2.2 Geomembrane

The geomembrane shall consist of new, first quality products designed and manufactured specifically for the purpose of this Works which shall have been satisfactorily demonstrated by prior testing to be suitable and durable for such purposes. The geomembrane rolls shall be seamless, high density polyethylene (HDPE - Density ≥ 0.94 g/ml) containing no plasticizers, fillers or extenders and shall be free of holes, blisters or contaminants, and leak free verified by 100% in line spark or equivalent testing. The geomembrane shall be supplied as a continuous sheet with no factory seams in rolls. The geomembrane will meet the property requirements as shown in Section 1.24.5 - Table 3.

Material Construction Quality Assurance testing by the Superintendent will be conducted in accordance with the project Specifications and CQA Plan.

The geomembrane seams shall meet the property requirements as shown in Section 1.24.6 - Table 4.



1.24.2.3 Acceptance by Superintendent

No materials will be accepted for delivery to Site or for progress payment unless all necessary manufacturer's quality assurance/quality control certification, including results of quality control testing has been provided to the Superintendent. All such data shall be supplied in sufficient time such that no delay shall be caused to the project program. Failure to provide the required certifications and test data and any resultant delay will not be grounds for an extension of time or removal of any commercial penalties that accompany the Contract.

1.24.3 Installation

1.24.3.1 Project Conditions

Geomembrane shall not be installed in the presence of standing water, while precipitation is occurring, during excessive winds or when material temperatures are outside the limits specified in these Specifications.

1.24.3.2 Surface Preparation

The surface to be lined shall be uniform and free of all sharp or angular objects that may damage the geomembrane prior to installation of the geomembrane.

The Contractor, liner sub-contractor and Superintendent shall inspect the surface to be covered with the geomembrane on each day's operations prior to placement of geomembrane to verify suitability.

The liner sub-contractor shall provide daily written acceptance for the surface to be covered by the geomembrane installation, to ensure surface suitability.

All subgrade and GCL surface damage caused by construction equipment and deemed unsuitable for geomembrane deployment shall be repaired by the Contractor prior to placement of the geomembrane. All repairs require the approval of the Superintendent and the liner sub-contractor.

1.24.3.3 Geomembrane Placement

No geomembrane shall be deployed until the applicable certifications and quality control certificates as specified are submitted to and approved by the Superintendent. Should geomembrane material be deployed prior to approval by the Superintendent it will be at the sole risk of the Contractor. If the material does not meet the project Specifications, it shall be removed from the Works area at no cost to the Principal.

The geomembrane shall be installed to the limits shown on the Drawings and essentially as shown on approved panel layout drawings.

The panels shall be laid in roof tile effect to allow continuous flow of water/leachate in the downward slope direction.

No geomembrane material shall be unrolled and deployed if the material temperatures are lower than 10°C unless otherwise approved by the Superintendent. The specified minimum temperature for material deployment may be adjusted by the Superintendent based on recommendations by the manufacturer and the Superintendent. Temperature limitations shall be defined in the pre-construction meeting. Only the quantity of geomembrane that will be anchored and seamed together in one day shall be deployed.



Installation of the geomembrane shall not result in scratching, scoring or crimping of the material.

The liner sub-contractor and Superintendent shall inspect the surface of each roll of material as it is being deployed or after deployment, but before welding, to verify that the material is free from visual defects such as tears, punctures, abrasions, indentations, cracks, thin spots or other faults in the material. If damages are identified, they are to be repaired or replaced according to these Specifications or as directed by the Superintendent.

NO vehicular traffic shall travel on the liner material.

The liner sub-contractor shall surcharge load all lining material during construction with appropriate material (i.e. sandbags or approved equivalent) to ensure the liner is protected from wind uplift and displacement, including down-slope creep. The frequency and spacing of the sandbag shall be as required based on Site conditions and lining sub-contractor's experience/recommendation. The sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the liner. The sandbags shall be filled with material that does not pose a risk of damage to the geosynthetics. The sandbags must be removed prior to placement of subsequent layers of synthetic liner material.

To prevent the geomembrane from creeping down-slope, it may be necessary to partially backfill the base of the anchor trench to pin the geomembrane in position while subsequent layers are installed.

Geomembrane placement shall not be carried out if moisture prevents proper surface preparation, panel placement or panel seaming. Moisture limitations shall be defined in the pre-construction meeting.

Damaged panels or portions of the damaged panels, which have been rejected, shall be marked and its removal from the Works area recorded.

The geomembrane shall not be allowed to "bridge over" voids or low areas in the subgrade. In these areas, the geomembrane shall be placed to allow the geomembrane to rest in intimate contact with the GCL. **Special attention to this aspect is to be paid when laying liner material in the leachate sump.**

Wrinkles caused by panel placement or thermal expansion shall be minimised in accordance with these Specifications.

Considerations on Site Geometry: In general, seams shall be oriented parallel to the line of the maximum slope. In corners and odd shaped geometric locations, the total length of field seams shall be minimised. Seams shall not be located at low points in the subgrade unless geometry requires seaming at such locations and if approved by the Superintendent.

Overlapping: The panels shall be overlapped prior to seaming to whatever extent is necessary to affect a good weld and allow for proper testing. In no case shall this overlap be less than 75mm.

All material offcuts shall be removed from the Works area and not simply left under the HDPE liner.



1.24.3.4 Defects and Damage

The Superintendent shall inspect the geomembrane as it is rolled out on the surface to be lined. The Superintendent shall be responsible for the acceptance or rejection of geomembrane being incorporated into the Works.

Manufacturing defects are areas where the geomembrane surface and/or texturing is not consistent and uniform. If a roll is suspected to be of inferior quality the Superintendent may take samples to assess its conformance with the Specifications. All testing is to be carried out in accordance with the appropriate standards and by a NATA accredited laboratory. Construction Quality Assurance testing results will determine the adequacy of the geomembrane.

Material replacement as a result of identified defects or damage shall be carried out by the Contractor. The Contractor will be liable for the costs associated with the replacement of all defective liner materials. The Contractor will be liable for the costs associated with the replacement of all damaged liner material, including being liable for all CQA testing costs as a result of replacing damaged liner material.

1.24.3.5 Seaming Procedures

Cold weather installations shall follow guidelines as outlined in GRI GM9.

No geomembrane material shall be seamed when liner temperatures are less than 10°C unless the following conditions are complied with:

- Seaming of the geomembrane at material temperatures below 10°C is allowed if the liner sub-contractor can demonstrate to the Superintendent, using prequalification test seams, that field seams comply with the project Specifications, the safety of the crew is ensured and geomembrane material can be repaired at temperatures less than 10°C.
- The liner sub-contractor shall submit to the Superintendent for approval, detailed procedures for seaming at low temperatures, possibly including the following:
 - Preheating of the geomembrane;
 - The provision of a tent or other device if necessary to prevent heat losses during seaming and rapid heat losses subsequent to seaming; and
 - Number of test welds to determine appropriate seaming parameters.

No geomembrane material shall be seamed when the sheet temperature is above 75°C as measured by an infrared thermometer or surface thermocouple unless otherwise approved by the Superintendent. This approval will be based on recommendations by the manufacturer and/or on a field demonstration by the liner sub-contractor using prequalification test seams to demonstrate that seams comply with the Specifications.

Seaming shall primarily be performed using automatic fusion welding equipment and techniques. Extrusion welding shall be used where fusion welding is not possible such as at patches, repairs and short (less than a roll width) runs of seams. Fusion welding can also be used on long patches, as recommended by the installer and agreed by the Superintendent.



The weld surfaces shall be cleaned prior to welding. The weld area shall be free of moisture, dust, debris, markings and foreign materials. In the case of extrusion welding, oxidation by-products shall be removed from the surface to be welded by grinding/buffing. Grind marks shall not be deeper than 10 % of the geomembrane thickness. Welding shall be performed shortly after grinding (within 30 minutes) so that surface oxide formation does not reform.

The Contractor shall be responsible for regularly checking calibrating (as per the manufacturer's recommendation) and recording the following items:

- Preheat air flow and temperature at the extruder nozzle;
- Extrudate flow and temperature at the barrel outlet; and
- Split copper wedge temperature on both contact points.

The Contractor shall utilise the machine mounted temperature readout (calibrated in accordance with the manufacturer's recommendation) or have an independently calibrated hand-held temperature measuring device to confirm temperatures of each and every welding machine prior to the commencement of any test or field welds. All information regarding the results gained from the temperature device shall be recorded for each welding machine.

Welding of all main joints between adjacent geomembrane panels (primary welds) shall be conducted using hot-wedge welding, producing two parallel seams with an air channel in between (dual track fusion welding). The hot-wedge welding shall be conducted using the split head wedge fusion weld method which will fuse the upper and lower overlapped geomembrane sheets.

The welding equipment shall be a fully automated device comprising of a heated copper wedge, pressure rollers and electronic controls. The copper wedge shall be controlled and constantly monitored by a programmable controller with an audible off temperature alarm and a variable speed drive unit. The copper wedge shall create two contact fusion areas of a minimum width of 15 mm and a 5 mm minimum wide void between each of the separate parallel weld zones. This void shall be created over the entire seam length to allow for field weld pressure testing.

The extrusion process is used primarily for detailed work and repair work (secondary weld) or where approved in areas that would be inaccessible to the dual track fusion weld (such as around structures, pipes and other penetrations). The extrusion welding shall be conducted using surface extrusion hand welders.

The minimum width of the surface extruded bead shall be 30 mm. The surface extrusion welder shall be semi-automated and equipped with electronic controls, which constantly monitor outputs for both preheat and extrudate. The unit shall be capable of pre-heating the sheet just prior to the casting of the extrudate over the upper and lower section of the weld zone.

The extruded granulate or rod for surface extrusion welding shall be manufactured from the same resin type used in the manufacture of the geomembrane. All physical properties shall be identical to those possessed by the geomembrane raw material. The manufacturer shall provide certified test data with each batch of welding granulate or rod. All granulate or rod supplied shall be packed to prevent the ingress of moisture and other contaminants. If necessary, the Contractor shall also employ an apparatus specifically built for drying granulate to ensure weld quality.



All geomembrane panels subject to hot wedge welding shall be overlapped by a minimum of 125 mm and a minimum of 75 mm for extrusion welding to allow for proper Construction Quality Assurance testing.

The Contractor shall ensure prior to any primary or secondary welding that weld zones be clean, free from moisture, dust and any other foreign matter. All weld zone surfaces shall be either cleaned or abraded no more than 30 minutes prior to the commencement of welding any seam. In extremely bad conditions it may be necessary for the liner Installer to clean and/or abrade the weld zone areas only minutes prior to the required weld.

Fishmouths or excessive wrinkles at the seam overlaps, shall be minimised and when necessary, cut along the ridge of the wrinkles back into the panel to affect a flat overlap. The cut shall be terminated with a keyhole cut (nominal 10 mm diameter hole) to minimise crack/tear propagation. The overlay shall subsequently be seamed. The keyhole cut shall be patched with an oval or round patch of the same base geomembrane material extending a minimum of 150 mm beyond the cut in all directions.

All primary welds used to connect panel end to sheets shall form T-joints (tees). These T-connections must be a distance of at least 0.5 m apart. All T-joints shall be patched. Patches are to be installed as detailed below. The welding seams of the geomembrane cannot cross (no cruciform connections).

1.24.3.6 Field Quality Control

The Superintendent shall be notified prior to all prequalification and production welding and testing, or as agreed upon in the pre-construction meeting.

Pre-qualification Test Seams

Test seams shall be prepared and tested by the liner sub-contractor to verify that seaming parameters (speed, temperature and pressure of welding equipment) are adequate.

Test seams shall be made by each welding technician and tested in accordance with ASTM D 5820 at the beginning of each seaming period. Test seaming shall be performed under the same conditions and with the same equipment and operator combination as production seaming. The test seam shall be approximately 3.5 m long for fusion welding and 1m long for extrusion welding with the seam centered lengthwise. As a minimum, test seams shall be made by each technician once every 4-6 hours or if any welding stoppage exceeds one hour; additional tests may be required with changes in environmental conditions.

Two 25 mm wide specimens shall be die-cut using calibrated equipment by the liner sub-contractor from each end of the test seam (total of four specimens). These specimens shall be tested by the liner sub-contractor using a calibrated field tensiometer, testing both tracks for peel strength and also for shear strength. Each specimen shall fail in the parent material and not in the weld, "Film Tear Bond" (FTD) failure. Seam separation equal to or greater than 25% weld area of the track width shall be considered a failing test.

The minimum acceptable seam strength values to be obtained for all specimens tested are listed in Section 1.24.6 - Table 4. All four specimens shall pass for the test seam to be a passing seam.

If a test seam fails, an additional test seam shall be immediately conducted. If the additional test seam fails, the seaming apparatus shall be rejected and not used for production seaming until the deficiencies are corrected and a successful test seam can be produced.



A sample from each test seam shall be labelled. The label shall indicate the date, geomembrane temperature, number of the seaming unit, technician performing the test seam and pass or fail description. The sample shall then be given to the Superintendent for archiving.

Field Seam Non-destructive Testing

All field seams shall be non-destructively tested by the liner sub-contractor over the full seam length before the seams are covered. Each seam shall be numbered or otherwise designated. The location, date, test unit, name of tester and outcome of all non-destructive testing shall be recorded and submitted to the Superintendent.

Section 1.24.7 - Table 5 sets out the minimum non-destructive weld testing that will be carried out by the liner sub-contractor.

Testing shall be carried out as the seaming Works progresses, not at the completion of all field seaming. All defects found during testing shall be numbered and marked immediately after detection. All defects found shall be repaired, retested and remarked to indicate acceptable completion of the repair.

Non-destructive testing shall be performed using vacuum box, air pressure or spark testing equipment.

Non-destructive testing shall be performed by experienced technicians familiar with the specified test methods. The liner sub-contractor shall demonstrate to the Superintendent all test methods to verify the test procedures are valid.

Extrusion seams shall be vacuum box tested by the liner sub-contractor in accordance with ASTM D 5820 and ASTM D 5641 with the following equipment and procedures:

- Testing is to begin no earlier than one (1) hour after welding.
- Equipment for testing extrusion seams shall be comprised of but not limited to: a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft rubber gasket attached to the base, porthole or valve assembly and a vacuum gauge; a vacuum pump assembly equipped with a pressure controller and pipe connections; a rubber pressure/vacuum hose with fittings and connections; a plastic bucket; wide brush or mop; and a soapy solution.
- The vacuum pump shall be charged, and the tank pressure adjusted to approximately 35 kPa (5 psig).
- The liner sub-contractor shall create a leak tight seal between the gasket and geomembrane interface by wetting a strip of geomembrane approximately 0.3 m by 1.2 m (length and width of box) with a soapy solution, placing the box over the wetted area, and then compressing the box against the geomembrane. The liner sub-contractor shall then close the bleed valve, open the vacuum valve, maintain initial pressure of approximately 35 kPa (5 psig) for approximately five seconds. The geomembrane shall be continuously examined through the viewing window for the presence of soap bubbles, indicating a leak. If no bubbles appear after five seconds, the area shall be considered leak free. The box shall be depressurised and moved over the next adjoining area with an appropriate overlap and the process repeated.
- All areas where soap bubbles appear shall be marked, repaired and then retested.
- At locations where seams cannot be non-destructively tested alternate non-destructive spark testing or equivalent shall be substituted; and,



- All seams that are vacuum tested shall be marked with the date tested, the name of the technician performing the test and the results of the test.

Double fusion seams with an enclosed channel shall be air pressure tested by the liner sub-contractor in accordance with ASTM D 5820 and the following equipment and procedures:

- Equipment for testing double fusion seams shall be comprised of but not limited to: an air pump equipped with a pressure gauge capable of generating and sustaining a pressure of 210 kPa (30 psig), mounted on a cushion to protect the geomembrane; and a manometer equipped with a sharp hollow needle or other approved pressure feed device.
- The testing activities shall be performed by the liner sub-contractor. Both ends of the seam to be tested shall be sealed and a needle or other approved pressure feed device inserted into the tunnel created by the double wedge fusion weld.
- The air pump shall be adjusted to a pressure of 210 kPa, and the valve closed. Allow two minutes for the air to come to equilibrium in the channel, and sustain pressure for five minutes.
- If pressure loss does not exceed 28 kPa after this five-minute period the seam shall be considered leak tight. Release pressure from the opposite end verifying pressure drop on needle to ensure testing of the entire seam. The needle or other approved pressure feed device shall be removed and the feed hole sealed; and,
- If loss of pressure exceeds 28 kPa during the testing period or pressure does not stabilise, the faulty area shall be located, repaired and retested by the liner sub-contractor.

Results of the pressure testing shall be recorded on the liner at the seam tested and on a pressure testing record.

In addition to the above tests, the welds are to be visually inspected to assess the quality of the workmanship and the appearance of the welded seam. For wedge welds there needs to be a consistent “squeeze out” on the weld edge which is an indicator that the correct temperature and pressure were used during installation. In the case of extrusion fillet welds, the weld appearance shall be smooth, uniform and free of streaks and lumps. In addition, there shall be no obvious scoring, notches or deep scratches introduced by the surface grinding.

Destructive Field Seam Testing

One destructive test sample per 150 linear metre seam length of fusion/wedge weld and 120 linear metre of extrusion weld shall be taken by the liner sub-contractor from a random location specified by the Superintendent. The liner sub-contractor shall not be informed in advance of the sample location. In order to obtain test results prior to completion of geomembrane installation, samples shall be cut by the liner sub-contractor as directed by the Superintendent as seaming progresses.

Section 1.24.7 - Table 5 sets out the minimum destructive weld testing that will be carried out by the liner sub-contractor.



All field samples shall be marked with its sample number and seam number. The sample number, date, time, location and seam number shall be recorded. The liner sub-contractor shall repair all holes in the geomembrane resulting from obtaining the seam samples. All patches shall be vacuum box tested, spark tested or air pressure tested (for long repairs undertaken using wedge welds). If a patch cannot be permanently installed over the test location the same day of sample collection, a temporary patch shall be tack welded or hot air welded over the opening until a permanent patch can be affixed.

The destructive sample size shall be 300 mm wide by 1m long with the seam centered lengthwise. The sample shall be cut into three equal sections and distributed as follows: one section given to the Superintendent as an archive sample; one section given to the Superintendent for laboratory testing as specified below; and one section retained by the liner sub-contractor for field testing as specified below.

For field testing, the liner sub-contractor shall cut, using a calibrated die cutter, 10 identical 25 mm wide replicate specimens from its sample. The liner sub-contractor shall test five specimens for seam shear strength and five for peel strength. Peel tests will be performed on both inside and outside weld tracks. To be acceptable, all five test specimens must pass the stated criteria in Section 1.22.6 with less than 25% weld area separation. If the field test weld is acceptable, the sample qualifies for testing by the testing laboratory. If the field test weld is unacceptable in accordance with the above, then the weld is deemed failed and is to be treated accordingly.

Independent seam testing arranged by the Superintendent shall be conducted in accordance with ASTM D 6392. Laboratory testing is the ultimate confirmation of the acceptability of the weld quality. To be acceptable, all five test specimens must pass the stated criteria in Section 1.22.6 with less than 25% weld area separation.

Reports of the results of examinations and testing shall be prepared and submitted to the Superintendent.

For field seams, if a laboratory test fails, that shall be considered as an indicator of the possible inadequacy of the entire seamed length corresponding to the test sample. Additional destructive test portions shall then be taken by the liner sub-contractor, typically 3 m on either side of the failed sample and laboratory seam tests shall be performed. Passing tests shall be an indicator of adequate seams. Failing tests shall be an indicator of inadequate seams and the testing process repeated. All seams represented by the destructive test location shall be repaired with a cap-strip, extrusion welded, or wedge welded (long patches) to all sides of the capped area. All cap-strip seams shall be non-destructively vacuum box or air pressure tested until adequacy of the seams is achieved. Cap-strip seams exceeding 50 m in length shall be destructively tested. All costs associated with additional sampling and testing, including laboratory testing, shall be at the Contractor's expense.

Identification of Defects

Panels and seams shall be inspected by the liner sub-contractor and Superintendent during and after panel deployment to identify all defects, including holes, blisters, undispersed raw materials and signs of contamination by foreign matter.



Evaluation of Defects

Each suspect location on the liner (both in geomembrane seam and non-seam areas) shall be non-destructively tested using one of the methods described in this Section. Each location which fails non-destructive testing shall be marked, numbered, measured and posted on the daily "installation" drawings and subsequently repaired.

If a destructive sample fails the field or laboratory test, the liner sub-contractor shall repair the seam between the two nearest passed locations on both sides of the failed destructive sample location.

Defective seams, tears or holes shall be repaired by re-seaming or applying an extrusion or wedge welded cap-strip.

Re-seaming may consist of either:

- Removing the defective weld area and re-welding the parent material using the original welding equipment; or
- Re-seaming by extrusion welding along the overlap at the outside seam edge left by the fusion welding process. Wedge welding can be used for long repairs.

Blisters, larger holes and contamination by foreign matter shall be repaired by patches and/or extrusion weld beads as required. Each patch shall extend a minimum of 150 mm beyond all edges of the defects.

All repairs shall be measured, located and recorded.

Verification of Repairs on Seams

Each repair shall be non-destructively tested using either vacuum box, spark testing or air pressure testing (long repairs) methods. Tests which pass the non-destructive test shall be taken as an indication of a successful repair. Failed tests shall be re-seamed and re-tested until a passing test results. The number, date, location, technician and test outcome of each patch shall be recorded.

Daily Field Installation Reports

At the beginning of each day's Works, the liner sub-contractor shall provide the Superintendent with daily reports for all Works accomplished on the previous Works day. Reports shall include the following:

- Total amount and location of geomembrane placed;
- Total length and location of seams completed, name of technicians doing seaming and welding unit numbers;
- Drawings of the previous day's installed geomembrane showing panel numbers, seam numbers and locations of non-destructive and destructive testing;
- Results of prequalification test seams;
- Results of non-destructive testing; and,
- Results of vacuum/spark/air pressure testing of repairs.

Destructive test results shall be reported prior to covering of liner or within 48 hours whichever is the soonest.



1.24.3.7 Liner Acceptance

Geomembrane liner will be accepted by the Superintendent when:

- The entire installation is finished or an agreed-upon subsection of the installation is finished;
- All liner sub-contractor's QC documentation is completed, submitted and approved by the Superintendent;
- Verification of the adequacy of all field seams and repairs and associated geomembrane testing is complete;
- Leak detection survey completed and all leaks repaired; and,
- All CQA testing on the installed material has been completed and approved by the Superintendent.

1.24.3.8 Disposal of Scrap Materials

On completion of installation, the liner sub-contractor shall dispose of all waste and scrap material in a location approved by the Superintendent, remove equipment used in connection with the Works herein, and shall leave the Site in a neat acceptable manner. No scrap material shall be allowed to remain on or under the geomembrane surface.

1.24.4 Materials Properties and Testing Scope

1.24.4.1 General

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

In the context of quality systems and management, these Specifications represent Manufacturing Quality Control (MQC).

Note: Manufacturing Quality Control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in these Specifications.

1.24.4.2 Definitions

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

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



1.24.4.3 Manufacturing Specifications and Quality Control

The quality of the geomembranes shall be in accordance with the requirements of the Geosynthetic Research Institute (GRI) – GM13. The minimum Specifications for a quality HDPE geomembrane product is contained in GRI Test Method GM13 Standard Specification for “*Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes*”.

In addition to the above, the Contractor is to provide a statement on the origin of the resin, its identification (type and lot number), its production date and the maximum amount of recycled polymer material added to the raw resin must be included as well as certified copies of the quality control certificates issued by the resin supplier and reports on the tests conducted by the manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to this project.

1.24.4.4 Material Classification and Formulation

These Specifications cover high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.94 g/ml and higher as measured in accordance with ASTM D 1505 and D 792.

The base resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher for and have a melt flow index value per ASTM D 1238 of less than 1.0 g/10 min. Base resin density is measured without carbon black and additives added.

Resin for the geomembrane shall be virgin, first quality HDPE resin and shall not be intermixed with other resin types. Furthermore, it shall not contain more than 2% clean recycled polymer by weight of the resin and with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

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

1.24.4.5 Physical, Mechanical and Chemical Property Requirements

The geomembrane shall conform to the test property requirements prescribed in Section 1.24.5 – Table 3.

The properties of the geomembrane shall be tested at the minimum frequency shown in Section 1.24.5 - Table 3. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

1.24.4.6 Workmanship and Appearance

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

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



1.24.4.7 MQC Sampling

Sampling shall be in accordance with the specific test methods listed in Section 1.24.5 - Table 3. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

The number of tests shall be in accordance with the appropriate test methods listed in Section 1.24.5 – Table 3.

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

1.24.4.8 MQC Retest and Rejection

If the results of any test do not conform to the requirements of these Specifications, retesting to determine conformance or rejection shall be carried out in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

1.24.4.9 Packaging and Marketing

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

1.24.4.10 Certification

A manufacturer's certification that the material was manufactured and tested in accordance with the Specifications, together with a report of the test results shall be furnished at the time of shipment.

1.24.4.11 Construction Quality Assurance Testing

The Contractor shall provide manufacturer's test results for the rolls delivered to Site to demonstrate that the rolls meet the requirements of the Specifications. The test frequency shall be as set out in Section 1.24.5 -Table 3.

The Superintendent will arrange for independent Construction Quality Assurance testing of the material. In order to achieve this:

- The Superintendent will determine the location of where the samples are to be received, either at the point of manufacture, supplier's warehouse or on Site;
- The timing of when the sampling will occur is to be coordinated by the Superintendent, between all Parties, to ensure the most efficient sampling process and handover of the samples. This will either be during or immediately after manufacture or as soon as is reasonable following delivery to Site;
- The CQA Consultant or nominated representative (for non-local sampling) will be present at the point of sampling to monitor the sampling procedure and to receive the samples;
- The Contractor is responsible for providing all samples, as required, from the rolls of liner material that will or have been delivered to Site and handing the samples to the CQA Consultant; and,



- The CQA Consultant will arrange for the delivery and testing of the samples to be carried out at an independent NATA accredited laboratory.

The Construction Quality Assurance results from the independent laboratory shall take precedence over the test results provided by the manufacturer of the material. The Construction Quality Assurance testing shall be at the Principal's cost.

Any non-conformance in the delivered materials as identified by Construction Quality Assurance testing shall be addressed by the Contractor and thereafter, if the Superintendent rejects the material, the Contractor shall replace the non-conforming material with conforming material. Again, the delivery of new material will be subject to Construction Quality Assurance testing to demonstrate its conformance with the Specifications. Any replacement of non-conforming material and subsequent Construction Quality Assurance testing carried out by the Superintendent will be at the Contractor's cost.

The material delivered to Site shall meet the Specifications relative to the independent laboratory test results, for the material to be considered for incorporation into the Works.

Section 1.24.7 - Table 5 sets out the minimum Construction Quality Assurance testing that will be carried out by the Superintendent.



1.24.5 Geomembrane Material Specifications

The geomembrane shall have the minimum material Specifications as set out in Table 3:

Table 3: HDPE Geomembrane Material Specifications

Property	Test Method	HDPE Test Value – 2.00mm Smooth Textured	Testing Frequency (minimum)
Thickness (min. ave.) <ul style="list-style-type: none"> Lowest individual for 8 out of 10 values Lowest individual for any of the 10 values 	D 5994	nom. (-5%) - 10% - 15%	Per roll
Asperity Height (min. ave.) (1)	D 7466	0.40 mm	Every 2 nd roll (2)
Density (min. ave.);	D 1505/D 792	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) (3) <ul style="list-style-type: none"> Yield strength Break strength Yield elongation Break elongation 	D 6693 Type IV	29 kN/m 21 kN/m 12% 100%	9,000 kg
Tear Resistance (min. ave.)	D 1004	249 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	534 N	20,000 kg
Carbon Black Content - Particle size ~20 nm (range)	D 4218 (5)	2.0-3.0%	9,000 kg
Carbon Black Dispersion	D 5596	note (6)	20,000 kg
Stress Crack Resistance (4)	D 5397 (App.)	500 hr.	Per GRI GM10
Geomembrane Oxidative Induction Time (OIT) (min. ave.) (7) <p>(a) Standard OIT, and</p> <p>(b) High Pressure OIT</p>	D 8117 D 5885	100 min. 400 min.	90,000 kg
Geomembrane Oven Aging at 85°C (7) (11) <p>(a) Standard OIT (min. ave.) - % retained after 90 days, and</p> <p>(b) High Pressure OIT (min. ave.) - % retained after 90 days</p>	D 5721 D 8117 D 5885	55% 80%	Per each formulation
Geomembrane UV Resistance (8) (11) <p>(a) Standard OIT (min. ave.) or</p> <p>(b) High Pressure OIT (min. ave.) - % retained after 1,600 hrs (10)</p>	D 7238 D 8117 D 5885	N.R. (9) 50%	Per each formulation
Longitudinal Edge		Smooth on both sides	



(1) Of 10 readings, 8 out of 10 must be ≥ 0 (1) Of 10 readings, 8 out of 10 must be ≥ 0.35 mm, and lowest individual reading must be ≥ 0.30 mm; also see Note 6.

(2) Alternate the measurement side for double sided texture sheet.

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

Yield elongate is calculated using a gauge length of 33 mm.

Break elongation is calculated using a gauge length of 50 mm.

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

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

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

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

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

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

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

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

(11) Test results are to be less than 12 months old relative to the date of manufacture of the delivered geomembrane and the manufacturer is to provide certification that the resin is of the same formulation as the rolls supplied for the works.

For Notes, refer to GRI Test Method GM13 - <http://www.geosynthetic-institute.org/grispecs/gm13.pdf>

Minimum Average Roll Value (min. ave.) is defined as the Mean value less 2 standard deviations. Mathematically, this implies that 97.5% of the results of the tested specimens will exceed the min. ave.

The Regulatory Authority landfill design guidelines require that the manufacturer carry out both the standard AND high pressure tests for the Oxidative Induction Time and the Oven Aging properties of the geomembrane, as opposed to the GRI GM13 giving the manufacturer the option to choose which of the two tests to perform.

1.24.6 Geomembrane Weld Properties

The geomembrane shall have the minimum average weld properties as set out in Table 4, with the Sample Strength being applicable to a 25 mm wide, 2.0 mm thick sample. Weld properties are determined in accordance with GRI GM19a Standard Specification:

Table 4: Minimum Average Weld Properties

Property	Test Method	Sample Strength (N/25 mm)
Fusion/Wedge Weld - Shear strength	ASTM D 6392	700
Fusion/Wedge Weld - Peel strength	ASTM D 6392	530
Extrusion Weld – Shear Strength	ASTM D 6392	700
Extrusion Weld – Peel Strength	ASTM D 6392	455

1.24.7 Geomembrane CQA Testing

The geomembrane shall undergo the minimum Construction Quality Assurance testing as set out in Table 5:

Table 5: Geomembrane CQA Testing

Item	Property	Standard	Frequency
Construction Quality Assurance testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Thickness	ASTM D5994	Each roll
	Asperity Height	ASTM D 7466	One sample per 5,000 m ² , or every five rolls delivered to Site whichever is the greatest number of tests
	Density	ASTM D1505, ASTM D792	
	Tensile properties (yield and break stress, yield and break elongation)	ASTM D6693 type IV	
	Puncture resistance	ASTM D4833	
	Tear resistance	ASTM D1004	
	Carbon black content	ASTM D4218	
	Carbon black dispersion	ASTM D5596	
	Stress crack resistance	ASTM D5397	
	Geomembrane Oxidative induction time	ASTM D8117, ASTM D5885	One sample every 10,000 m ² , or resin type or manufacturing run
Start-up test weld	Welding equipment	N/A	Checked daily at start of Works, and whenever the welding equipment is shut-off for more than one hour. Also after significant changes in weather conditions



Item	Property	Standard	Frequency
	Weld conditions	N/A	Test weld strips will be required whenever personnel or equipment are changed and/or wide temperature fluctuations are experienced. Minimum 1.5 m continuous seam
Destructive weld testing	On-Site, hand tensiometer in peel and shear	ASTM D6392	Every 150 m (if fusion weld), Every 120 m (if extrusion weld)
	Off-Site — weld seam strength in peel and shear	ASTM D6392	Every 150 m (if fusion weld), every 120 m (if extrusion weld)
Non-destructive weld testing	N/A	Air pressure test, ASTM D5820 Vacuum box test, ASTM D5641	All seams over full length
Visual inspection of geomembrane	Smooth edges on both sides, tears, punctures, abrasions, cracks, indentations, thin spots, or other faults in the material.	N/A	Every roll
Thickness of geomembrane	On-Site	N/A	Five per 100 m, 20 m apart, taken at the edge of the sheet

Note:

1. All Construction Quality Assurance tests must be reviewed, accepted and reported by the CQA Consultant before deployment of the geomembrane.
2. All testing must be performed on samples taken from the geomembrane delivered to Site or at the supplier's/mannufacturer's premises under the CQA Consultant's inspection or delegated authority.
3. All laboratory tests must be performed in an independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state of the art practice and/or to account for the criticality of the application (i.e. to account for the importance of the geomembrane for the stability of Works).



1.25 Leachate Delivery Pipework

1.25.1 General

The leachate delivery pipework between the existing landfill leachate sumps on the Eastern Landfill and the new leachate pond is to consist of a DN110 PE100 PN16 pipe and is to be constructed in accordance with the Specifications and Drawings.

1.25.2 Installation

The pipes are to extend from all leachate sumps on the Eastern Landfill, up to the new leachate pond. The pipe routes are to be determined on site, by the Superintendent.

There is to be an isolation valve installed at the pond end of the pipeline. The isolation valve is to be positioned for easy access by the facility operators.

1.26 Fencing

The Contractor shall provide all materials, supervision, labour and equipment for the construction of the fencing and gates around the evaporation pond in accordance with the Specifications and Drawings.

The mesh fencing is to comply with *AS 1752.1:2010 "Chain Link Fabric Fencing – Security Fences and Gates – General Requirements"*.

The purpose of the permanent fencing is to limit the risk of unauthorised human and fauna access to the leachate ponds.

Fencing shall be 1.8 m high mesh fence with three strands of barbed wire above, resulting in a total fence height of approximately 2.3 m high mesh fence. All fencing material to be galvanized. The 1.8 gates are to have three strands of barbed wire on top to reflect a similar appearance as the fence configuration.

The fencing typical minimum detail includes the following:

- 1.8 m fence:
 - Corner posts – 50 mm x 3.5 mm NB pipe galvanised, capped @ 3,000 m;
 - Intermediate posts – 32 mm x 3.0 mm NB pipe galvanised, capped @ 3,000 mm, max 3.3 m centres;
 - Stays – 32 mm x 2.5 mm NB pipe galvanised;
 - Chain wire mesh – 1,800 x 50 x 2.5 mm KK heavy galvanised chain wire mesh;
 - Cable wires – 4.00 mm heavy galvanised plain wire – Helical x 3 rows;
 - Barbed wires – 1.60 mm heavy duty galvanised barbed wire – 3 rows; and,
 - Footings:
 - Posts – 250 diameter x 800 mm deep, full depth concrete foundation;



Final fencing details are to be provided by the Contractor, for approval by the Superintendent prior to installation.

1.27 Pond Safety System

The Contractor shall provide all materials, supervision, labour and equipment for the construction of the safety system within the leachate pond in accordance with the Specifications and Drawings.

The pond safety system consists of a number of polyethylene rope ladders, a minimum of 600 mm wide fixed around the pond perimeter.

The top of the rope ladders shall be attached to a spreader bar to maintain the rope ladder shape. The rope ladders shall be weighted along the ladder length to prevent the ladders from floating. The ladders shall be secured to the pond perimeter fencing at ground level or two star pickets in the event that there are no adjacent fence posts. In the event that star pickets are utilised, they are to have a minimum tensile resistant force of 150 kg per star picket at ground level (fixing level).

The proposed rope ladders and all associated fixings shall be proposed by the Contractor and approved by the Superintendent before installation. Fixings shall be weather resistant fixings and provide at least 20 years of service in the exposed environment and compatible with typical liquid waste conditions and exposure to UV radiation. The fixings shall be soft, so they pose no puncture risk to the underlying geomembrane liner.

1.28 Quality Assurance and Testing

1.28.1 General

The Contractor shall at all times be responsible for achieving the specified standards and demonstrating such achievement through testing and measurement and the provision of documentation which shall cover all Works under the Contract, both on-site and off-site and shall include the activities of all sub-contractors and suppliers. The exception being, that the Principal will be responsible for the quality of all Principal Supply Items.

1.28.2 Traceability

Traceability is required for all materials as stipulated in these Specifications or if not stipulated, as per the relevant Standard, Code of industry norm. The trace shall start at the specified or nominated source point and finish at the location where the material is incorporated into the Works.

Traceability shall apply to:

- HDPE Pipe and Fittings;
- Geosynthetic Clay Liner; and,
- HDPE Liner.



1.28.3 Inspection

The Superintendent or its nominated representative shall at all times be provided access to any facility where Works associated with the Contract is being performed, including the facilities of sub-contractors or suppliers either on-site, and any laboratory used for testing.

1.28.4 Testing Personnel

All quality control testing unless specified otherwise shall be carried out by a laboratory holding current NATA accreditation for all test methods referred to or required by these Specifications. NATA accreditation for all test methods shall be held at the time of tendering and be maintained until completion of the Contract. All test reports shall be NATA endorsed by a current NATA signatory approved for the laboratory conducting the testing.

Surveying processes to verify conformance shall be conducted by suitably qualified personnel, which includes:

- A qualified and experienced surveyor able to be a fulltime member of the Institution of Mining and Engineering Surveyors Australia;
- A surveyor licensed under the WA Licensing Board; or,
- A surveyor that has undertaken similar works and at the same level of responsibility for a minimum of five years and has a proven track-record of reliable survey works.

1.28.5 Sampling and Test Frequency

Sampling methods shall be unbiased and either random or systematic in concept or as specified. The minimum frequency of tests shall be as stipulated in these Specifications or if not stipulated, as per the relevant Standard, Code of industry norm.

1.28.6 Testing

1.28.6.1 *Limits of Work to be Tested*

The minimum frequency of tests shall be as stipulated in these Specifications.

1.28.6.2 *Test Methods*

The tests methods shall be as stipulated in these Specifications or equivalent alternative test methods approved by the Superintendent.

1.28.7 Measurement and Test Equipment

Measurement and test equipment shall include all equipment necessary for the proper setting out and for production and Construction and Construction Quality Assurance testing of the Works. Calibration and certification of test equipment shall comply with NATA stipulations.

1.28.8 Records and Reporting

The Contractor shall complete all As-Constructed and quality verification documentation and submit all records, to the Superintendent at regular intervals during the Contract period as agreed with the Superintendent.



1.28.9 Payment for Quality Control and Testing

The cost of Construction Quality Control testing to the extent required by these Specifications shall be borne by the Contractor.

The Principal shall pay for all Construction Quality Assurance testing as stipulated in these Specifications.

1.29 As-Constructed Drawings

The Contractor is to provide a set of As-Constructed drawings in AutoCAD format and A3 size hard copy. The As-Constructed drawings are to show the following minimum detail:

- General Site earthworks layout – pre-liner installation surface;
- Pond layout including:
 - Perimeter bund positions;
 - Anchor trench positions;
 - Leachate pipe positions – pipe crown;
 - Fence position; and,
 - Any changes to the Approved For Construction Drawings that occurred during construction, marked in red or if changes are extensive, changes to the drawings, with modifications indicated within clouds to clearly indicate changes to the original Drawings.

