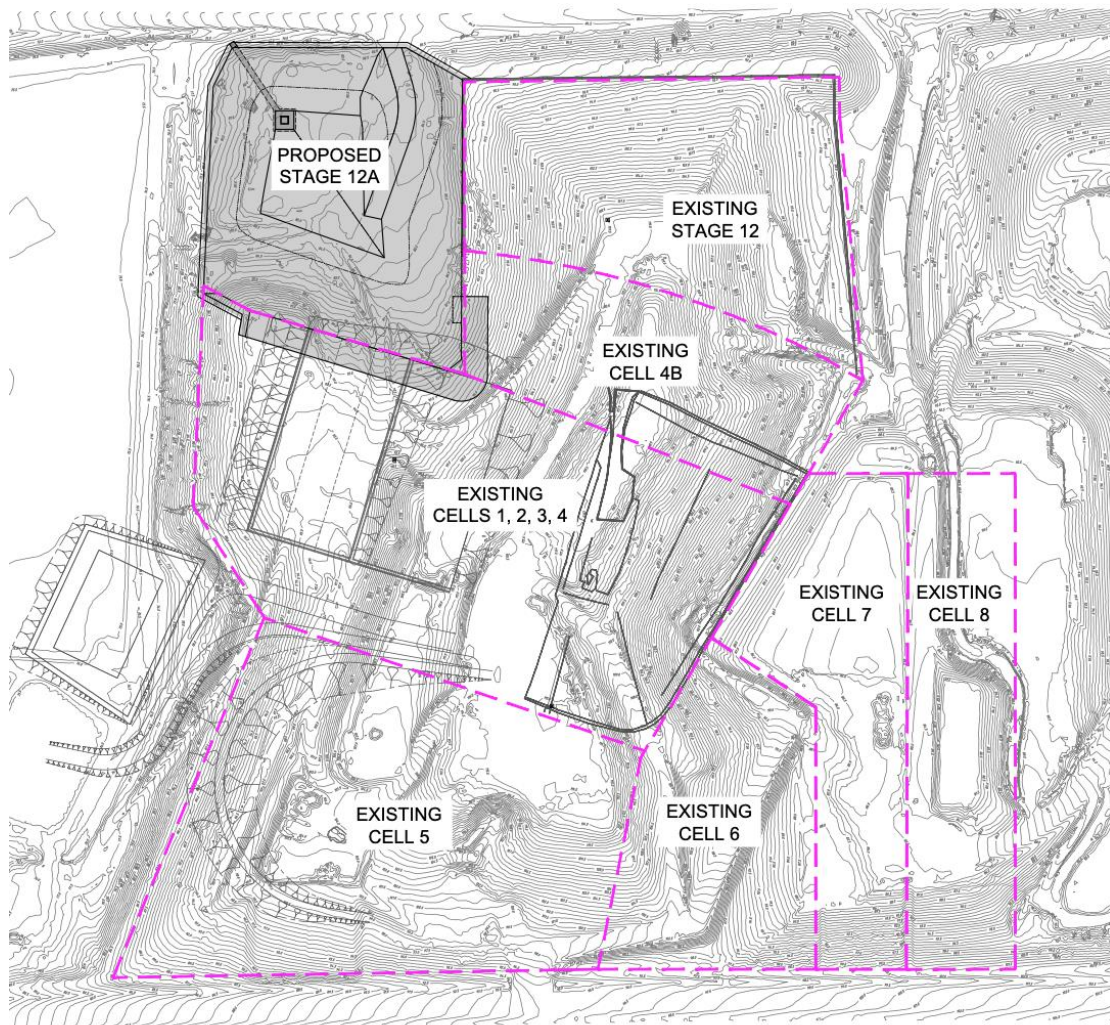


BANKSIA ROAD LANDFILL, DARDANUP

CELL 12A LANDFILL CONSTRUCTION

ISSUE FOR CONSTRUCTION – SPECIFICATION



Cell 12A Site Plan

Prepared for

CLEANAWAY SOLID WASTE

IW Projects Pty Ltd

6 Anembo Close, DUNCRAIG, WA 6023

Mobile: 0402 909 291 email: iwatkins@iwprojects.com.au

Revision:

Date of Issue:

Final

27 Oct 2020

Table of Contents

Table of Contents	ii
1 Specification	1
1.1 Description of Works	1
1.2 Works Not Included	1
1.3 Principal	1
1.4 Principal Supply Items	2
1.5 Quality Assurance, Inspection and Reporting	3
1.6 Contract Limits	4
1.7 Areas Available to the Contractor	4
1.8 Contractor's Facilities	4
1.9 Pollution and Spillage	4
1.10 Hours of Site Work	4
1.11 Site Meetings/Briefings	5
1.12 Remedial Work During Defects Liability Period	5
1.13 Water for use in the Works	5
1.14 Setting Out and Measurement of Quantities	5
1.15 Weather	6
1.16 Liaison with Others	6
1.17 Provision for Traffic	6
1.18 Demobilisation	6
1.19 Vegetation and Site Clearing	6
1.20 Earthworks	7
1.20.1 Introduction	7
1.20.2 Earthworks Inspection	7
1.20.3 Applicable Documents	8
1.20.4 Definitions	8
1.20.5 Handover	8
1.20.6 Excavation	9
1.20.7 Fill Materials	1
1.20.8 Foundation Preparation	1
1.20.9 Fill Placement and Compaction	2
1.21 Supply and Installation of Geosynthetic Clay Liner	5
1.21.1 General	5
1.21.2 Installation	8
1.21.3 Materials Properties and Testing Scope	12
1.21.4 GCL Material Specification	15
1.21.5 GCL CQA Testing	17
1.22 Supply and Installation of HDPE Geomembrane	18
1.22.1 General	18
1.22.2 Products	22
1.22.3 Installation	23
1.22.4 Materials Properties and Testing Scope	32
1.22.5 HDPE Geomembrane Material Specifications	36
1.22.6 HDPE Geomembrane Weld Properties	38
1.22.7 HDPE CQA Testing	38
1.22.8 HDPE Geomembrane – Sample Warranty Document	40
1.23 Supply and Installation of Geotextiles	41
1.23.1 Scope of Work	41
1.23.2 Geotextile Requirements	41
1.23.3 Geotextile CQA Testing	42
1.23.4 Manufacturing Specifications and Quality Control	43

1.23.5	Delivery, Storage and Handling.....	43
1.23.6	Placement	44
1.24	Leachate Collection Pipework.....	46
1.24.1	General.....	46
1.24.2	Pipe Drilling	46
1.24.3	Installation	46
1.25	Supply and Installation of Leachate Drainage Aggregate	47
1.25.1	General.....	47
1.25.2	Installation Timing.....	47
1.25.3	Leachate Drainage Material	47
1.26	Leak Detection Survey	49
1.27	Leachate Collection Sump	49
1.27.1	General.....	49
1.27.2	Installation	49
1.28	Leachate Access Concrete Platform	50
1.29	Leachate Access Point Infrastructure.....	50
1.30	Quality Assurance and Testing.....	50
1.30.1	General.....	50
1.30.2	Traceability.....	50
1.30.3	Inspection	50
1.30.4	Testing Personnel	50
1.30.5	Sampling and Test Frequency	51
1.30.6	Testing.....	51
1.30.7	Measurement and Test Equipment.....	51
1.30.8	Records and Reporting	51
1.30.9	Payment for Quality Assurance and Testing	51
1.31	As-Constructed Drawings	52

Copyright and Disclaimer

This document has been prepared by IW Projects Pty Ltd solely for the benefit and use of Cleanaway Solid Waste Pty Ltd.

IW Projects Pty Ltd shall assume no liability or responsibility to any third party arising out of the use of or reliance upon this document by any third party.

IW Projects Pty Ltd owns the copyright to this document and the commercial use of the document without the written permission of IW Projects Pty Ltd is strictly prohibited.

1 Specification

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;
- Excavation to suit design layout, including stockpiling of the various excavated materials (soft material, clayey material, unsuitable material) as instructed by the Superintendent;
- Construction and reshaping of cell access and associated stormwater drainage system;
- Construction of landfill cell and leachate extraction system, including only the first lift of leachate drainage aggregate up side batters;
- Undertaking leak detection survey of all lined areas where leachate drainage aggregate has been placed;
- 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:

- The supply of road surfacing material;
- The supply of the GCL, bentonite paste, geomembrane (including welding rods) and geotextiles; however, the Contractor will be responsible for the liner material from the time of acceptance from the Principal through to the end of the Contract; and,
- Leachate pumping system.

1.3 Principal

The Principal for the project will be Cleanaway Solid Waste Pty Ltd.

1.4 Principal Supply Items

The Principal shall supply the GCL (including bentonite paste as required), geomembrane (including welding rods as required) cushion geotextile and separation geotextile. This material will have been through the necessary quality control process in order to confirm its suitability and acceptability for the Works prior to the Contractor taking possession of the liner material. Once handed over to the Contractor, the liner material becomes the responsibility of the Contractor. Any damage to the liner post-handover to the Contractor will be rectified by the Contractor, at no cost to the Principal.

The liner material will either be handed over to the Contractor on site on the back of a flatbed truck, packed within sea containers or appropriately stacked. The Contractor is to fully inspect the liner material and once inspected, sign off on a handover certificate confirming the acceptability of the material and where relevant, documenting any pre-existing damage to the liner material for which the Principal is liable. The Superintendent is to be present during the handover inspection to confirm the state and cause of any pre-existing damaged material.

All handling of the liner material is to be as set out in these Specifications and as recommended by the material manufacturer.

Any damaged material due for replacement by the Contractor 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 will order the additional material and carry out the necessary quality control process prior to providing the Contractor with the replacement material. The Contractor will be liable for all of the Principal's costs associated with the replacement of the damaged liner material, including quality control costs. The Contractor is to be aware that there will likely be a significant delay in replacing the damaged material, which could be in excess of eight weeks from the time of order (depending on the material type).

During installation of the liner material, there is the possibility that some of the liner material may be rejected by the Superintendent as being of inferior quality and hence requiring replacement. Where the inferior liner quality is as a result of manufacturing defects, as agreed between the Parties, the Contractor will not be liable for the replacement of the rejected materials, the Principal will replace the rejected material with acceptable material at no cost to the Contractor.

Typically, liner installation has a wastage factor, including overlaps, of between 8% and 15% of the overall area being lined, depending on the complexity of the installation project. The Contractor is to use the liner material in an efficient and professional manner to limit wastage. Should the Superintendent identify that there is excessive material wastage, an independent opinion will be sought to determine if the material wastage is deemed unreasonable. The Contractor will be liable for the cost of any deemed unreasonably excessive wastage.

The Contractor will include in its Works insurance the full replacement value of all Principal supplied liner material. This will include the cost of all necessary quality control testing. Prior to finalising the Works insurance, the Contractor is to obtain the full insurance value of the Principal supplied liner material from the Superintendent. This value is to be included in the Contractor's Works insurance policy.

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 Conformance Quality Control testing carried out by the Superintendent as stipulated in these Specifications. Any repeat Conformance Quality Control 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, Conformance Quality Control 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 Principal shall supply the GCL, bentonite paste, geomembrane, welding rods, cushion geotextile and separation geotextile. This material will have been through the necessary quality control process in order to confirm its suitability and acceptability for the Works prior to the Contractor taking possession of the liner material. Any damaged material due for replacement by the Contractor 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 Conformance Quality Control 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 Works 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, dust suppression and leak detection testing (if required) will be available on Site via a standpipe adjacent to the primary dam, which is approximately 2 km by road from 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 confirm survey control to the Superintendent to the grades and levels shown on the Drawings.

Where necessary, 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.

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 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.

1.17 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.

1.18 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.

1.19 Vegetation and Site Clearing

There are minor areas of weeds and low shrubs that require removal. By the Contractor.

There is no clearing of native vegetation associated with the Works.

Prior to the construction works, the Principal will arrange for the removal of all landfill associated infrastructure that is located within the works area.

1.20 Earthworks

1.20.1 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;
- Excavation in the vicinity of the existing liner material to facilitate the tie-in for the new Works into the existing liner system;
- Grading and compaction of cell foundation, the leachate extraction sump and cell perimeter bunds;
- Excavation and haulage of fill, moisture conditioning, placement and compaction to the required grades and levels;
- Construction Quality Control testing and sampling; and,
- Control and diversion of surface water and run-off from within the Works area.

1.20.2 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 landfill base and side slopes;
- Approval of the compaction method used;
- Inspection of all fill placement and compaction activities;
- Inspection of all third party 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 CQA 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.

1.20.3 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.

1.20.4 Definitions

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

- "Standard Maximum Dry Density" as determined in accordance with AS 1289.5.1.1-2003.

1.20.5 Handover

On handover of the Site to the Contractor, the Contractor is to undertake a detailed base 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 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 base survey will be compared to the Principal's base survey (which may have been undertaken prior to Site handover) and the handover base 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 base survey will be used for calculating quantities of Works undertaken throughout the project.

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

1.20.6 Excavation

1.20.6.1 General

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

The Contractor is to remove all soft or unsuitable material from the base or side slopes of the existing void.

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

1.20.6.2 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.

Excess excavated material not used as fill material will be stockpiled separately, in accordance with the Stockpile Management Plan, which has a maximum road haulage of 2.5 km from the Works area or in a location as directed by the Superintendent, again, within 2.5 km of the Works area.

The Contractor is to form and maintain material stockpiles as indicated by the Superintendent. To conserve space, the material stockpiles will consist of multiple layers of deposited spoil and will be managed accordingly by the Contractor, including the minimisation and containment of silt runoff.

All excavated material that is deemed unsuitable to be used as fill, by the Superintendent, will be stockpiled separately, in accordance with the Stockpile Management Plan, which has a maximum road haulage of 2.5 km from the Works area or in a location as directed by the Superintendent, again, within 2.5 km of the Works area.

1.20.6.3 Excavation Around Existing Liner

To facilitate the tie-in to the existing liner, the Contractor is required to excavate soil and possibly some waste from the vicinity of the existing liner anchor trench. All excavation around the existing liner material is to be carried out with extreme care so as not to damage the liner material. Any damage caused to the liner material by the Contractor, will be repaired by the Contractor, at no cost to the Principal.

1.20.7 Fill Materials

1.20.7.1 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.

1.20.7.2 Material

Select fill material shall comprise naturally occurring silty/clayey 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 with a maximum particle dimension no larger than 40 mm. The suitability of the fill material will be determined by the Superintendent prior to incorporation into the Works.

1.20.7.3 Unsuitable Material

The term "unsuitable material" shall apply to 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 in accordance with the Stockpile Management Plan, which has a maximum road haulage of 2.5 km from the Works area or in a location as directed by the Superintendent, again, within 2.5 km of the Works area.

1.20.8 Foundation Preparation

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

The foundation of the cell shall be graded to maintain a uniform fall to the lowest part of the cell. 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 foundation to confirm the Works meets the specified requirements.

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

1.20.9 Fill Placement and Compaction

1.20.9.1 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.

1.20.9.2 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 Standard Maximum Dry Density (SMDD) determined in accordance with AS 1289.5.1.1. 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 Standard Maximum Dry Density (SMDD) determined in accordance with AS 1289.5.1.1.

1.20.9.3 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).

1.20.9.4 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 from either:

- Sand Replacement Density Testing (AS1289.5.3.1) in conjunction with the Hilf Method (AS1289.5.7.1); and/or,
- Nuclear Densometer methods (AS1289.5.8.1) in association with standard compaction (AS1289.5.1.1).

Where sand replacement density testing is carried out, a Hilf compaction test shall be carried out for each sand replacement test.

Where nuclear densometer methods are used, 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.

1.20.9.5 *Dimensions and Tolerances*

The finished levels of fill shall be within -25 mm and +25 mm of the design levels. In the case of the landfill base, the finished levels are still required to attain the minimum gradients stated in the Drawings (minimum 1% along the valley drain and 3% into the valley drain). 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.

1.20.9.6 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.

1.20.9.7 Surface Confirmation

The completed surface shall be surveyed by the Contractor on a maximum 20 m grid to confirm the accuracy of construction. As a minimum, the survey is to include the levels along the floor valley drains and ridge lines, the position of the leachate sump and the perimeter bunds. The survey is also to include calculations of the fall along the floor valley drains and the fall into the valley drains. 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.

1.20.9.8 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.

1.20.9.9 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. Where destruction, scarring, damage or defacing has occurred as a result of the operations, repairing, replanting, reseeding, or other correction measures shall be undertaken to the satisfaction of the Superintendent. All fencing shall be reinstated to its original condition.

1.21 Supply and Installation of Geosynthetic Clay Liner

1.21.1 General

1.21.1.1 GCL 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 Tendering. 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.

The Contractor shall provide all 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 shall be approved in writing by the Superintendent.

1.21.1.2 Submittals

Submittal Documentation

The Contractor is to submit the following to the Superintendent for review and approval, within a reasonable time to expedite 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 Tender, 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. Roll-end joins shall not occur on the side slope. Where this is unavoidable, the join is to include an anchor trench as indicated in the Drawings. The joins between GCL panels on the side slope and the base shall be located in 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.

1.21.1.3 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.

Third-Party CQA Consultant

The Principal will appoint an independent third-party 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 third-party CQA Consultant include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on interpretation of 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 third-party 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 third-party CQA Consultant to enable the full inspection of the Works.

1.21.1.4 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 Principal and handed over to 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 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.

1.21.1.5 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;
- Covering of the GCL – normal practice and in the event of rain;
- Surcharging of the GCL within two weeks of installation;
- Measurement and payment schedules;
- Health and safety; and
- Surcharging of the GCL within two weeks of installation.

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

1.21.2 Installation

1.21.2.1 Project Conditions

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

1.21.2.2 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.

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.

1.21.2.3 GCL Placement

The GCL shall be installed such that the panels are anchored at the crest of the slope and are continuous down side walls/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.

Where necessary, roll-end joints on the side slopes are to be anchored as indicated in the Drawings.

No longitudinal panel joins are to be within 2 m of the leachate drain invert.

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.

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 material in the central leachate collection valley drain and 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 the geomembrane liner material.

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

Longitudinal overlap joints between panels shall be formed by overlapping the panels and utilising the additional bentonite in the edge treatment to seal the joint. Roll end joints or other non-longitudinal joints will be sealed by either bentonite paste or powder/granules. 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 (in conjunction with an anchor trench).

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 paste or powder. The presence of loose bentonite may affect welding of overlying geomembranes and may also influence interface friction.

GCL installed on slopes is to be fixed in anchor trenches. This is to secure the GCL and prevent it from sloughing or slipping down the side slopes during construction. The front edge of the trench is to be rounded to prevent the development of stress concentrations on the GCL or any other geosynthetics. The GCL shall be laid on the inside wall and base of the trench only and the trench shall be cleared of any debris, gravel or loose material before the GCL is installed. The trench shall be backfilled and compacted with suitable selected fill to 95% MDD.

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.

GCL is to be surcharged by the subsequent installation of leachate drainage aggregate within two weeks of installation.

1.21.2.4 Joining Procedures

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

- Longitudinal joins – 300 mm
- Roll-end joins:
 - On landfill base – 500 mm; and,
 - On landfill side slope – 1.5 m (with anchor trench).

1.21.2.5 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.

1.21.2.6 Damage and Defects

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, and shall make a determination of whether identified damage is a function of manufacture or installation of the GCL.

Manufacturing defects are areas where the geotextile is missing or 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 shall take samples to assess its Conformance Quality Control with the Specifications. All testing is to be carried out in accordance with the appropriate standards and by a NATA accredited laboratory. Conformance Quality Control testing results will determine the adequacy of the GCL.

1.21.2.7 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 granules/paste as per normal jointing requirements.

1.21.2.8 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.

1.21.2.9 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.

1.21.3 Materials Properties and Testing Scope

GCL material is a Principal supply item and the Principal will manager all related quality control of the material. The following section has been included to provide the Contractor with information on the type of material that will be supplied and hence, enable the Contractor to determine the installation process, time required and necessary equipment.

In addition, this is also a demonstration of the extent and involvement in confirming the quality of the installed material and hence the cost associate if the Principal is required to replace damaged material, being at the Contractor's cost. Even though the material will be supplied by the Principal, the Environmental Regulator requires that the stated process be followed.

1.21.3.1 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.

1.21.3.2 Manufacturing Specifications

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 following bentonite Specifications shall be verified every 50 tonnes of the product:

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

* Carbonate here implies calcite, calcium carbonate or other soluble or partially soluble carbonate minerals.

1.21.3.3 Physical and Mechanical Property Requirements

The GCL shall conform to the test property requirements prescribed in Section 1.21.4 - Table 1.

1.21.3.4 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.

1.21.3.5 MQC Sampling

Sampling shall be in accordance with the specific test methods listed in Section 1.21.4 - 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 1.21.4 – 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.

1.21.3.6 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 done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

1.21.3.7 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.

1.21.3.8 Conformance Quality Control Testing

The Superintendent will arrange for independent Conformance Quality Control testing of the material in accordance with Section 1.21.5 - Table 2. All laboratory Conformance Quality Control testing will have been carried out prior to the Contractor taking position of the liner material. Only the visual inspection will occur on site as the material is being unrolled.

1.21.4 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 Specifications

Property	Test	Frequency	Value
Montmorillonite content	XRD (X-ray diffraction) Quantitative Mineralogy Analysis	50 tonnes	> 70 wt%
Carbonate content (1)		50 tonnes	1-2 wt%
Bentonite form		50 tonnes	Natural Na-bentonite or >80 wt% Sodium as activated bentonite
Particle size	AS 1289-3.6.2	50 tonnes	
Cation exchange capacity	(Methylene Blue Method)	50 tonnes	≥ 70 meq/100 g (or cmol/kg)
Free Swell (bentonite) (min. ave.)	ASTM D5890	50 tonnes	≥ 24 mL/2g
Moisture Content (bentonite) (min. ave.) (2)	ASTM D5993	2,500 m ²	≤ 25% at Manufacture ≤ 35% Site Samples
Fluid Loss (bentonite) (min. ave.) (2)	ASTM D5891	50 tonnes	18 ml max.
Top Geotextile Mass (min. ave.) (3)	ASTM D5261	20,000 m ²	≥ 240 g/m ² Non-woven
Mass of GCL (min. ave.) (4)	ASTM D5993	2,500 m ²	≥ 4,290 g/m ²
Mass of Bentonite (min. ave.) (4)	ASTM D5993	2,500 m ²	≥ 3,700 g/m ²
Bottom Geotextile Mass (min. ave.)	ASTM D5261	20,000 m ²	≥ 350 g/m ² Woven/Non-woven
Composite layer Thickness (Dry) (min. ave.)	ASTM D1777	2,500 m ²	≥ 6 mm
Elongation (MD) (min. ave.)	ASTM D4632	20,000 m ²	≥ 10%
Tensile Strength (min. ave.)	ASTM D6768	20,000 m ²	≥ 12 kN/m
Peel Strength (min. ave.)	ASTM D6496	2,500 m ²	360 N/m
Permeability (max. ave.) (2)	ASTM D5887	25,000 m ²	≤ 3.0 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 $\geq 100 \text{ g/m}^2$ 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.

1.21.5 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
Conformance Quality Control testing (sampled at the point of manufacture or on site, as determined by the Superintendent)	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
	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
	Mass/unit length of bentonite in overlaps	ASTM D5993 Visual inspection	1 sample every 3 rd roll Every roll
	Moisture content of bentonite	AS 1289.2.1.1	1 sample per 2,500 m ²
	Swell index/free swell of clay	ASTM D5890	1 sample per 1,500 m ²
	Water absorption	ASTM D5891	1 sample per 1,500 m ²
	Peel strength (for needle-punched products only)	ASTM D6496	1 sample every 3 rd roll
	Tensile strength	ASTM D4595	1 sample per 10,000 m ²
	Index flux	ASTM 5887	1 sample per 10,000 m ²
Visual inspection of GCL	Colour, thickness, needle punching, presence of needles or broken needles, and sewing density or other faults in the material.		Every roll
Thickness of GCL (i.e. uniformity of bentonite distribution) and apparent variations in the as placed moisture distribution.	On-site		Each roll during placement. If thickness appears to be variable a check of the variability of the mass per unit area shall be conducted

1.22 Supply and Installation of HDPE Geomembrane

1.22.1 General

1.22.1.1 *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 Tendering. 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. It is noted that there is a one roll width wearing layer down the embankment batter in the vicinity of the leachate extraction point, below the leachate extraction pipework (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 shall be approved in writing by the Superintendent.

1.22.1.2 *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:

- Documentation of manufacturer's qualifications;
- Manufacturer's Quality Control program manual or descriptive documentation;
- A material properties sheet, including at a minimum all properties specified, including test methods used;
- Typically, 0.5 m of roll length of material delivered to Site to be used by the Superintendent for Conformance Quality Control testing as required in Section 1.22.7 - Table 5;
- If any proposed change in liner sub-contractor from what was approved at Tender, 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;
- Liner sub-contractor Quality Control Program; and,

- Resin Supplier's name, resin production plant identification, resin brand name and number, production date of the resin, resin Manufacturer's quality control certificates, and certification that the properties of the resin meet the requirements for the project.

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:

- Manufacturer's warranty;
- 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.

1.22.1.3 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.

Third-Party CQA Consultant

The Principal will appoint an independent third-party 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 third-party CQA Consultant include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on interpretation of 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 third-party 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 third-party CQA Consultant to enable the full inspection of the Works.

1.22.1.4 Delivery, Storage and Handling

Each roll of geomembrane delivered to the Site shall 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.

Geomembrane shall be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.

Rolls shall be stored away from high traffic areas. Continuously and uniformly support rolls on a smooth, level prepared surface.

Rolls shall not be stacked more than three (3) high.

Handling of geomembrane rolls is to be via the use of a spreader bar. The bar must be capable of supporting the full weight of the roll without significant bending;

1.22.1.5 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 HDPE;
- GCL/subgrade conditions, dewatering responsibilities and GCL/subgrade maintenance plan;
- Deployment techniques, especially placement of geomembrane on top of GCL with the geomembrane textured side down;
- 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.

1.22.1.6 Material Warranty

As required by these Specifications, the Sample Warranty Document to be completed is included in the Section 1.22.8.

1.22.1.7 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.

1.22.2 Products

1.22.2.1 Manufacturing Quality Control Documentation

The test methods and frequencies used by the manufacturer for quality control/quality assurance of the above geomembrane prior to delivery shall be in accordance with Section 1.22.5 - 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.

1.22.2.2 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 1.22.5 - Table 3.

Material Conformance Quality Control 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 1.22.6 - Table 4.

1.22.2.3 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.

1.22.3 Installation

1.22.3.1 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.

1.22.3.2 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.

1.22.3.3 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.

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 GCL and subbase.

Sandbags or equivalent ballast shall be used as necessary to temporarily hold the geomembrane material in position under the foreseeable and reasonably expected wind conditions. Sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the geomembrane.

Geomembrane placement shall not be done 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 material in the central leachate collection valley drain and 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.

1.22.3.4 Seaming Procedures

Cold weather installations shall follow guidelines as outlined in GRI GM 9.

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 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.

If the Contractor's welding equipment does not have its own factory fitted temperature gauges to undertake the above measurements, the Contractor shall 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 (dualtrack 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 digital temperature gauge display or 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.

1.22.3.5 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 1.22.6 - 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 1.22.7 - Table 5 sets out the minimum non-destructive weld testing that will be carried out by the liner sub-contractor.

Testing shall be done 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 0.3m by 1.2m (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 5 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 5 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 2 minutes for the air to come to equilibrium in the channel, and sustain pressure for 5 minutes.

- If pressure loss does not exceed 28 kPa after this 5-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 1.22.7 - 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.

1.22.3.6 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.

1.22.3.7 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 geomembrane surface.

1.22.4 Materials Properties and Testing Scope

1.22.4.1 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.

These Specifications also present a recommended warranty, which is focused on the geomembrane material itself.

1.22.4.2 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) – is also 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.

1.22.4.3 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 GM-13 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.

1.22.4.4 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 two per cent 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.

1.22.4.5 Physical, Mechanical and Chemical Property Requirements

The geomembrane shall conform to the test property requirements prescribed in Section 1.22.5 – Table 3.

The properties of the geomembrane shall be tested at the minimum frequency shown in Section 1.22.5 - Table 3. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

1.22.4.6 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.

1.22.4.7 MQC Sampling

Sampling shall be in accordance with the specific test methods listed in Section 1.22.5 - 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 1.22.5 – 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."

1.22.4.8 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 done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

1.22.4.9 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.

1.22.4.10 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.

1.22.4.11 Warranty

A Manufacturer's Warranty of the Quality of the material shall be furnished to the Superintendent before any liner material is installed in the Works. The Manufacturer's Warranty shall accord with the Sample Warranty Document included in the Section 1.22.8.

1.22.4.12 Conformance Quality Control 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 1.22.5 -Table 3.

The Superintendent will arrange for independent Conformance Quality Control 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 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 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 Conformance Quality Control testing shall be at the Principal's cost.

Any non-conformance in the materials as identified by the Conformance Quality Control 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 Conformance Quality Control testing to demonstrate its conformance with the Specifications. Any replacement of non-conforming material and subsequent Conformance Quality Control 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 1.22.7 - Table 5 sets out the minimum Conformance Quality Control testing that will be carried out by the Superintendent.

1.22.5 HDPE Geomembrane Material Specifications

The HDPE 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 Double 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
Oxidative Induction Time (OIT) (min. ave.) (7) <ul style="list-style-type: none"> (a) Standard OIT, and (b) High Pressure OIT 	D 3895 D 5885	100 min. 400 min.	90,000 kg
Oven Aging at 85°C (7) <ul style="list-style-type: none"> (a) Standard OIT (min. ave.) - % retained after 90 days, and (b) High Pressure OIT (min. ave.) - % retained after 90 days 	D 5721 D 3895 D 5885	55% 80%	Per each formulation
UV Resistance (8) <ul style="list-style-type: none"> (a) Standard OIT (min. ave.) or (b) High Pressure OIT (min. ave.) - % retained after 1,600 hrs (10) 	D 7238 D 3895 D 5885	N.R. (9) 50%	Per each formulation

(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.*

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.

1.22.6 HDPE 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

1.22.7 HDPE CQA Testing

The geomembrane shall undergo the minimum Conformance Quality Control testing as set out in Table 5:

Table 5 – Geomembrane CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Thickness	ASTM D5994	Each roll
	Density	ASTM D1505, ASTM D792	One sample per 5,000 m ² , or every five rolls delivered to Site whichever is the greatest number of tests
	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 D1603	
	Carbon black dispersion	ASTM D5596	
	Stress crack resistance	ASTM D5397	One sample every 10,000 m ² , or resin type or manufacturing run
	Oxidative induction time	ASTM D3895, ASTM D5885	
Start-up test weld	Welding equipment		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
	Weld conditions		Test weld strips will be required whenever personnel or equipment are changed

Item	Property	Standard	Frequency
			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		Air pressure test, ASTM D5820 Vacuum box test, ASTM D5641	All seams over full length
Visual inspection of geomembrane	Tears, punctures, abrasions, cracks, indentations, thin spots, or other faults in the material.		Every roll
Thickness of geomembrane	On-Site		Five per 100 m, 20 m apart, taken at the edge of the sheet

Note:

1. All Conformance Quality Control tests must be reviewed, accepted and reported by the Superintendent before deployment of the geomembrane.
2. All testing must be performed on samples taken from the geomembrane delivered to Site under the Superintendent inspection.
3. All laboratory tests must be performed in a third-party independent accredited geosynthetics 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 safety of Works). Revisions must be approved by the Environmental Regulator before application.

1.22.8 HDPE Geomembrane – Sample Warranty Document

ABC GEOMEMBRANE COMPANY LIMITED WARRANTY

Warranty No. _____
Project No. _____
Effective Date _____
Purchaser Name _____
Project Name _____
Address/Location _____
City, State, Post Code, Country _____
Geomembrane Type/Description _____

ABC Geomembrane Company warrants each ABC geomembrane to be free from manufacturing defects (as defined by the contract's material specifications) and to be able to withstand normal weathering for a period of 5 years from the above effective date for normal use in approved applications.

This Limited Warranty does not include damages or defects in the ABC geomembrane resulting from acts of God, casualty or catastrophe including but not limited to: earthquakes, floods, piercing hail, tornadoes or force majeure. The term "normal use" as used herein does not include, among other things, the exposure of ABC geomembranes to harmful chemicals, abuse of ABC geomembranes by machinery, equipment or people; improper Site preparation or covering materials, excessive pressures or stresses from any source or improper application or installation. ABC geomembrane material warranty is intended for commercial use only and is not in effect for the consumer as defined in the Magnuson Moss Warranty or any similar federal, state or local statutes. The Parties expressly agree that the sale hereunder is for commercial or industrial use only.

Should defects or premature loss of use within the scope of the above Limited Warranty occur, ABC Geomembrane Company will, at its option, repair or replace the ABC geomembrane on a pro-rata basis at the then current price in such manner as to charge the Purchaser/User only for that portion of the warranted life which has elapsed since purchase of the material. ABC Geomembrane Company will have the right to inspect and determine the cause of any alleged defect in the ABC geomembrane and to take appropriate steps to repair or replace the ABC geomembrane if a defect exists which is covered under this warranty. This Limited Warranty extends only to ABC's geomembrane, and does not extend to the installation service of ABC Geomembrane Company or third Parties.

Any claim for any alleged breach of this warranty must be made in writing, by certified mail, to the CEO/President of ABC Geomembrane within ten (10) working days of becoming aware of the alleged defect. Should the required notice not be given, the defect and all warranties are waived by the Purchaser, and Purchaser shall not have any rights under this warranty. ABC Geomembrane Company shall not be obligated to perform repairs or replacements under this warranty unless and until the area to be repaired or replaced is clean, dry and unencumbered. This includes, but is not limited to, the area made available for repair and/or replacement of ABC geomembrane to be free from all water, dirt sludge, residuals and liquids of any kind. If after inspection it is determined that there is no claim under this Limited Warranty, Purchaser shall reimburse ABC Geomembrane Company for its costs associated with the Site inspection.

In the event the exclusive remedy provided herein fails in its essential purpose, and in that event only, the Purchaser shall be entitled to a return of the purchase price for so much of the material as ABC Geomembrane Company determines to have violated the warranty provided herein. ABC Geomembrane Company shall not be liable for direct, indirect, special, consequential or incidental damages resulting from a breach of this warranty including, but not limited to, damages for loss of production, loss of profits, personal injury or property damage. ABC Geomembrane Company shall not be obligated to reimburse Purchaser for any repairs, replacement, modifications or alterations made by Purchaser unless ABC Geomembrane Company specifically authorised, in writing, said repairs, replacements, modifications or alteration in advance of them having been made. ABC Geomembrane Company's ability under this warranty shall in no event exceed the replacement cost of the material sold to the Purchaser for the particular installation in which it failed.

ABC Geomembrane Company neither assumes nor authorises any person other than the undersigned of ABC Geomembrane Company to assume for it any other additional liability in connection with the ABC geomembrane made on the basis of the Limited Warranty. The "Limited Warranty on the ABC geomembrane herein is given in lieu of all other possible material warranties, either expressed or implied, "and by accepting delivery of the material, Purchaser waives all other possible warranties except those specifically given.

Limited Warranty is extended to the purchaser/owner and is non-transferable and non-assignable, i.e. there are no third party beneficiaries to this warranty.

Purchaser acknowledges by acceptance that the Limited Warranty given herein is accepted in preference to any and other possible materials warranties.

ABC GEOMEMBRANE COMPANY MAKES NO WARRANTY OF ANY KIND OTHER THAN THAT GIVEN ABOVE AND HEREBY DISCLAIMS ALL WARRANTIES, BOTH EXPRESSED OR IMPLIED, OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THIS IS THE ONLY WARRANTY THAT APPLIES TO THE MATERIALS REFERRED TO HEREIN AND ABC DISCLAIMS ANY LIABILITY FOR ANY WARRANTIES GIVEN BY ANY OTHER PERSON OR ENTITY, EITHER WRITTEN OR ORAL

ABC GEOMEMBRANE COMPANY'S WARRANTY BECOMES AN OBLIGATION OF ABC GEOMEMBRANE COMPANY TO PERFORM UNDER THE WARRANTY ONLY UPON RECEIPT OF FINAL PAYMENT

I hereby stated that I have read the above and foregoing Limited Warranty and agree to such by signing hereunder.

DATE _____

PURCHASER NAME: _____ ABC GEOMEMBRANE COMPANY

SIGNATURE: _____ (CEO/President of Authorised Representative)

TITLE _____

SWORN BEFORE ME THIS _____ DAY OF _____ 2020

1.23 Supply and Installation of Geotextiles

Geotextile material is a Principal supply item and the Principal will manager all related quality control of the material. The following section has been included to provide the Contractor with information on the type of material that will be supplied and hence, enable the Contractor to determine the installation process, time required and necessary equipment.

In addition, this is also a demonstration of the extent and involvement in confirming the quality of the installed material and hence the cost associate if the Principal is required to replace damaged material, being at the Contractor's cost. Even though the material will be supplied by the Principal, the Environmental Regulator requires that the stated process be followed.

1.23.1 Scope of Work

The scope of Works incorporates the installation of geotextiles as specified and to the extent shown in the Drawings.

The Principal will supply the geotextile liner materials.

The Contractor shall provide all supervision, labour and equipment for the installation of the geotextiles in accordance with these Specifications and Drawings, this includes the supply of sandbags to hold down the liner material.

Prior to installation, all geotextiles to be incorporated in the Works shall be approved in writing by the Superintendent.

1.23.2 Geotextile Requirements

The geotextile shall be 100 % polyester or polypropylene (with the exception of inhibitors and/or carbon black added for UV resistance), non-woven needle-punched geotextile. Geotextiles shall not be made from recycled materials.

The geotextile filaments shall be rot proof, chemically stable and shall have low water absorbency. It shall resist de-lamination and maintain its relative position in the geotextile.

Geotextiles shall be free of flaws that may have an adverse effect on the physical and mechanical properties of the geotextiles.

Geotextiles shall be free of any manufacturing broken-off needles. Should any needles be found either by visual inspection or the Superintendent using a metal detector, the Contractor is to thereafter undertake continuous inspection of both sides of each and every roll of geotextile prior to installation. Inspection is to be via a Superintendent approved method of metal detection. Should more than one manufacturing needle or part thereof be detected per 200 m² of liner, the Superintendent may reject the complete roll. Should more than 10 rolls, each with more than one needle per 200 m² be detected, the Superintendent may reject that complete batch of geotextile. The cost incurred by the Contractor in carrying out the metal detection testing will be dealt with as a variation to the Contract Sum. The costs in replacing any rejected material will be covered by the Principal.

Geotextiles shall be stabilised against ultraviolet radiation to the degree that twelve (12) months exposure of the geotextile to sunlight shall not reduce its strength to less than 90% of the specified values.

The geotextiles shall have the minimum material Specifications as set out in Table 6:

Table 6: Geotextile Material Specifications

Geotextile Application	Parameter	Specifications	Test Method & Frequency
Geotextile Cushion Layer Geofabrics supply, A84	Wide Strip Tensile Strength (MD/XMD) (min. ave.)	≥ 52.0/52.0 kN/m	AS 3706-2 1 sample/5,000 m ²
	Grab Tensile Strength (MD/XMD) (min. ave.)	≥ 4,000/4,000 N	AS 3706-2 1 sample/5,000 m ²
	Trapezoidal Tear Strength (MD/XMD) (min. ave.)	≥ 1,200/1,200 N	AS 3706-3 1 sample/5,000 m ²
	CBR Burst Strength (min. ave.)	≥ 9,000 N	AS 3706-4 1 sample/5,000 m ²
Geotextile Separation Layer and UV Protection Layer Geofabrics supply, A24	Wide Strip Tensile Strength (MD/XMD) (min. ave.)	≥ 14.0/14.0 kN/m	AS 3706-2 1 sample/5,000 m ²
	Grab Tensile Strength (MD/XMD) (min. ave.)	≥ 850/850 N	AS 3706-2 1 sample/5,000 m ²
	Trapezoidal Tear Strength (MD/XMD) (min. ave.)	≥ 345/345 N	AS3706-3 1 sample/5,000 m ²
	CBR Burst Strength (min. ave.)	≥ 2,500 N	AS 3706-4 1 sample/5,000 m ²

1.23.3 Geotextile CQA Testing

The geotextile shall undergo the minimum CQA testing as set out in Table 7:

Table 7 – Geotextile CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Wide Strip Tensile Strength	AS 3706–2	1 sample per 5,000 m ²
	Grab Tensile Strength	AS 3706–2	1 sample per 5,000 m ²
	Trapezoidal Tear Strength	AS 3706–3	1 sample per 5,000 m ²
	CBR Burst Strength	AS 3706–4	1 sample per 5,000 m ²
Destructive tests	Tensile tests for joints.	AS 3706–6	As required.
Visual inspection of geotextile	Colour, thickness, tears, holes, punctures, needle-punching, presence of needles or broken needles, and other faults in the material.		Each roll during placement.

1.23.4 Manufacturing Specifications and Quality Control

The quality of the geotextile shall be in accordance with the requirements of the Geosynthetic Research Institute (GRI) — GT12(b). The minimum specifications for quality geotextile products are contained in GRI Test Method GT12(b), the standard specification for “*Test methods and properties for nonwoven geotextiles used as protection (or cushioning) materials*”.

1.23.5 Delivery, Storage and Handling

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

- Manufacturer's name;
- Product identification (material type);
- Date of manufacture, batch number, polymer type;
- Roll number;
- Roll length;
- Roll weight; and,
- Roll width.

The geotextile rolls shall be handled and stored in such manner that no damage occurs to the geotextile or its protective wrapping. The geotextile rolls shall be wrapped with weatherproof wrapping to protect material from ultraviolet degradation and moisture uptake. In the event that rolls are damaged, the Superintendent shall assess the extent of the damage and consider possible rejection of the damaged rolls.

A dedicated area shall be used for the storage of all geotextile material delivered to Site.

The material shall be stored as follows:

- Away from high traffic areas, but sufficiently close to the active Works area to minimise handling;
- On 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;
- Appropriate slings used when lifting to prevent damage to any material; and,
- Under no circumstances may the geotextile 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.

1.23.6 Placement

Geotextile placement shall be as follows:

- The Contractor is to provide a panel layout diagram to the Superintendent for approval a minimum of one (1) week prior to any geotextile installation. Once approved by the Superintendent, the geotextile is to be installed in accordance with the approved panel layout.
- No installation of geotextile is to occur until the Superintendent has approved all manufacturer's QA/QC documentation and all Conformance Quality Control testing has been concluded and the material approved by the Superintendent;
- Installation shall be performed by an Installer who has installed a minimum of 50,000 m² of geotextile of the type specified or similar product, using the same type of installation apparatus to be used in the current project.
- No placement shall occur during heavy rain events or during excessively windy conditions;
- Appropriate lifting equipment is to be used to ensure safe and efficient material placement;
- The cushion geotextile shall be placed above the finished geomembrane. The Contractor shall ensure that all CQA testing and recording on the geomembrane surface has been fully completed and approved by the Superintendent prior to the installation of the geotextile protection material. The geomembrane surface upon which the cushion geotextile will be deployed shall be free of any sharp objects, stones, debris, standing water, or other potentially damaging objects;
- The geotextile shall not be installed until inspection of the geomembrane has been undertaken and deemed suitable and in accordance with these Specifications by the Superintendent;
- The geotextile shall be installed such that the sheets are anchored at the crest of the slope and are rolled down side walls/slopes, so as to keep the geotextile free of wrinkles and folds. The arrangement of the geotextile sheets shall be according to a predetermined layout plan;
- The panels shall be laid in roof tile effect to allow continuous flow of water/leachate in the downward slope direction.
- 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.
- During placement, care must be taken not to entrap (either within or beneath the geotextile) stones, excessive dust or moisture that could damage the geomembrane or hamper subsequent seaming;

- Jointing between sheets shall be formed by overlapping by a minimum of 150 mm for all longitudinal joins and roll end joins on the floor of the cell. There is to be a minimum of 1 m roll end overlap on the slopes, with the lower roll being under the upper roll. The areas to be joined shall be clean and free of foreign matters;
- Jointing of the sheets shall be conducted by stitching or by heat bonding using an approved hot-air device. The joints shall be continuous along the full join length. On slopes they shall be constructed parallel to the slope gradient. Where heat bonding is used, the Contractor shall ensure that the bonding method does not pose any risks of damage to the underlying geomembrane. In case of stitching, the thread type must be polymeric with chemical and UV light resultant properties equal or greater than that of the geotextile itself;
- The geotextile protection material shall not have cross joints on side slopes steeper than 1 V : 5 H;
- The entire surface area of each and every roll shall be inspected by the Superintendent (for example, during unrolling/installation) to ensure that there is no damage or other faults in the material (such as significant and obvious variability in thickness/mass per unit area, tears, holes or presence of broken needles). If damage is identified, it will need to be repaired according to these Specifications or as instructed by the Superintendent;
- Geotextiles installed on slopes must be fixed in anchor trenches as indicated in the Drawings;
- The geotextile shall be laid on the inside wall and base of the anchor trench only, the trench shall be cleared of any debris, gravel or loose material before the geotextile is installed. The trench shall be backfilled and compacted with low hydraulic-conductivity soils;
- Adequate sandbags left in place to prevent exposed geotextile material being blown around by wind. This includes separation geotextile over aggregate layer, UV protection geotextile on south eastern batter and cushion geotextile on the remainder of the southern batter. It is for the Contractor to determine the extent of ballast required, which must last until the end of the Defects Liability Period. As a minimum, there is to be a sandbag every 2m along the geotextile join overlaps (longitudinal and roll end) and at 6m centres down the middle of each roll; and,
- The separation geotextile shall be installed on top of the leachate aggregate layer in a similar manner to the cushion geotextile, the exception being that there is to be no vehicles driven on the separation geotextile under any circumstances.

Installation shall comply with the manufacturer's requirements, details of which shall be provided by the Superintendent prior to installation.

If the geotextile has been damaged (by tears, holes or otherwise) during installation, it can be repaired by patching a new piece of geotextile made from the same material. Any soil or other material that may have penetrated the damaged geotextile shall first be removed before any repair could be conducted. On slopes, the patch shall be double-seamed into place with the seams 5 mm to 20 mm apart. Elsewhere a patch shall be spot-seamed in place with a minimum of 300 mm overlap in all directions.

1.24 Leachate Collection Pipework

1.24.1 General

The scope of Works incorporates the supply and installation of the leachate collection and delivery pipes as specified and to the extent shown in the Drawings. There are a range of pipe diameters utilised for different applications.

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

The jointing of pipes shall be by butt welding or electro-fusion welding carried out by an appropriately qualified technician. Evidence of suitable qualification shall be provided to the Superintendent prior to the commencement of any pipe welding.

Bends shall be either pre-manufactured standard pipe fittings or specially manufactured bends.

All cut edges and welded joints shall be neat, clean and smooth.

1.24.2 Pipe Drilling

Portions of the leachate collection pipework are to be drilled. The extent and method of drilling is as indicated in the Drawings.

Where required, drilling of polyethylene pipe shall **not** be undertaken on the lined area of the Works.

Drilled pipe shall be cleaned out of all drill cuttings prior to being installed in the Works.

1.24.3 Installation

Polyethylene pipes shall be stored, handled, transported and installed in accordance with the manufacturer's requirements.

Polyethylene pipes shall not be subject to rough handling, particularly during loading and unloading operations. Pipes shall be suitably protected from scouring from lifting equipment. Pipes shall be suitably supported during lifting to prevent distortion or buckling.

Polyethylene pipes shall be lifted gently into position so as to avoid damage to the pipe and landfill liner materials. The pipes shall not be dragged or dropped. The Contractor shall only carry out this Works in the presence of the Superintendent who shall be given at least 24 hours prior notice in writing. Any damage sustained or suspected shall be thoroughly examined and rectified to the satisfaction of the Superintendent. All costs involved shall be borne by the Contractor.

Each pipe shall be accurately laid and aligned in terms of grade and position as indicated in the Drawings. Leachate collection pipes shall be placed directly on the cell liner material and pipe side support material (leachate drainage aggregate) shall be carefully placed and compacted to provide haunch support to the pipe without damage to the landfill cell liner materials or displacement of the pipe.

Leachate extraction pipework up the side slope shall be held in position prior to the construction of the concrete leachate access platform. Care is to be taken to prevent the pipework from sliding down the embankment slope and damaging the cell liner and leachate sump.

All foreign material shall be removed from the interior surface of the pipes before they are installed in the Works.

1.25 Supply and Installation of Leachate Drainage Aggregate

1.25.1 General

The scope of Works incorporates the supply and placement of leachate drainage aggregate as specified and to the extent shown in the Drawings.

The Contractor shall provide all materials, supervision, labour and equipment for the placement of the leachate drainage aggregate in accordance with these Specifications and Drawings.

Prior to placement, all aggregate to be incorporated in the Works shall be approved in writing by the Superintendent.

1.25.2 Installation Timing

The Contractor is to install the leachate aggregate over the cushion geotextile as soon as is reasonably possible during the progression of the work, **but definitely within two weeks of the installation of any GCL**. Any area of GCL installed in the Works, which is to be covered by leachate drainage aggregate, is not to be left for more than two weeks without being surcharged with the leachate drainage aggregate.

The Contractor is to program the Works such that the various liner installation and QA activities occur concurrently such that the aggregate is placed within two weeks of any area of GCL having been installed.

1.25.3 Leachate Drainage Material

1.25.3.1 Characteristics

Leachate Drainage Material shall consist of clean, virgin aggregate (blue metal), free of organic matter, lumps of clay or other deleterious material and be free of fine-grained material. The maximum particle size of the cell floor drainage material shall be no greater than 37.5 mm. Crushed limestone is not acceptable due to its susceptibility to degradation by leachate.

The Material shall comply with the grading as set out in Table 8. Variance in grading between 37.5 mm and 13.75 mm will be acceptable; however, no aggregate will be greater than 37.5 mm and no more than 5% will be below 13.75 mm and 2% less than 4.75 mm:

Table 8 – Aggregate Grading

Sieve Size	Percentage Passing
37.5	100
26.5	70 - 100
13.75	0 - 5
4.75	0 - 2
2.36	0 - 1

The Contractor shall provide to the Superintendent a 20 kg sample of the proposed material and copies of test results from an independent NATA accredited laboratory, confirming compliance with the Specifications prior to its use in the Works.

1.25.3.2 Placement

The Contractor shall only carry out the Works in the presence of the Superintendent who shall be given at least 24 hours prior notice in writing. Any damage sustained or suspected to have occurred to the underlying liner layers and substrate shall be thoroughly examined and rectified to the satisfaction of the Superintendent. All costs involved shall be borne by the Contractor.

The leachate drainage material shall be placed in a layer of 300 mm minimum thickness. It is essential that this placement operation be carried out such that no excessive stress is imparted to the underlying liner or substrate Works so as not to damage any previous Works. In particular, the Contractor shall take into account: temperature effects; loads imposed by haulage vehicles, spreading vehicles, etc; drainage material placement techniques; and geomembrane waves.

The aggregate shall be installed above the cushion geotextile in the landfill cell to the extent shown on the Drawings. The aggregate layer is to be placed up the landfill perimeter side slopes to a maximum vertical height of 4.5 m above the toe of the side slope. The remainder of the leachate drainage aggregate will be progressively installed by others as the waste height increases.

The Contractor shall place the aggregate on the liner and not spill or push the aggregate out onto the liner. Any waves formed in the liner materials as a result of the aggregate being pushed out shall be repaired by the Contractor, at no cost to the Principal.

The drainage material shall be spread with a small dozer or similar machine with a maximum ground contact pressure of 50 kPa. The machine shall operate over at least 300 mm thickness of drainage material at all times. The machine shall not take large cuts into heaped material. This may result in rear track drift and dig into the material causing potential abrasion or rupture of the liner below. The machine shall not slew or brake suddenly unless over a designated temporary haul road or tipping area where the drainage material is maintained at a minimum thickness of 800 mm as measured from the bottom of the deepest ruts in the aggregate to the surface of the geomembrane. When no longer required, temporary haul roads and tipping areas shall be removed by spreading over adjacent uncovered areas of membrane.

Vehicles spreading aggregate are not to turn on the aggregate on the side slope and are only to travel up and down the slope, not sideways on the slope.

Haulage vehicles shall remain on designated haulage roads and tipping areas at all times. No haulage vehicles are to travel on the side slopes.

1.26 Leak Detection Survey

The Contractor is to carry out a leak detection survey of all geomembrane lined areas. The survey is to be carried out in accordance with ASTM D7007 *Standard Practice for Electrical Method of Locating Leaks in Geomembrane Covered with Water or Earth Materials*, or a similar methodology as approved by the Superintendent. The survey is to be undertaken by a suitably qualified sub-contractor (it could be the main Contractor) that has been approved by the Superintendent. Any water used during the survey is to be clean and clear and not silt laden, as silt will block the leachate extraction system.

The leak detection survey is to be undertaken once the geomembrane has been installed and the drainage aggregate has been placed on top of the geomembrane, but before the separation layer has been installed.

The Contractor is to provide adequate notification (minimum 48 hours) to the Superintendent of when any installation of survey equipment or any survey is being carried, out along with a method statement of how the Contractor proposes to undertake the Work activity.

The results of the leak detection survey are to be provided to the Superintendent for review prior to any repairs being undertaken.

The Contractor is to repair and test/resurvey all identified leaks in the lining system.

If the Superintendent deems that the area of aggregate removal and replacement is substantial and there is the likelihood that the liner could have been further damaged by the repair activity, the Superintendent may instruct that the area be resurveyed for any further leaks. As an indication, if there is a need to use mechanical equipment to remove and replace the aggregate, the repair is likely to be considered as substantial.

Where applicable, the separation geotextile is only to be installed once the Superintendent has approved the completion of leak detection survey and that all repairs have been carried out, including any testing or resurvey if necessary.

1.27 Leachate Collection Sump

1.27.1 General

The leachate collection sump is to be constructed in accordance with the Specifications and Drawings. The sump consists of a prefabricated HDPE box shutter, which forms part of the landfill lining system. The box shutter is then filled with reinforced concrete and the flexible landfill lining system welded to the box shutter lid. The leachate extraction pipework is then strapped to the exposed concrete portion of the sump arrangement.

The Contractor is to ensure that the exposed concrete portion of the sump is accurately surveyed and the information provided in the As-Constructed drawings.

1.27.2 Installation

During the installation of the leachate collections sump, care is to be taken to minimise the number of liner joins within the sump. This applies to both the double GCL layers and HDPE layer.

1.28 Leachate Access Concrete Platform

The Works consist of the construction of one leachate access platform. The access platform is to be constructed to the detail and at the location as indicated in the Drawings.

Leachate extraction pipework up the side slope shall be held in position prior to the construction of the concrete leachate access platform. Care is to be taken to prevent the pipework from sliding down the embankment slope and damaging the cell liner and leachate sump.

1.29 Leachate Access Point Infrastructure

The leachate access point infrastructure including pump, rising main, delivery mechanism and associated fittings does not form part of the Contract Works. For consistency across all leachate sumps, this aspect of the installation will be completed by the contractor that deals with all leachate extraction on Site.

1.30 Quality Assurance and Testing

1.30.1 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.

1.30.2 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;
- Leachate Sump Box Shutter;
- Geosynthetic Clay Liner;
- HDPE Liner; and,
- Geotextiles.

1.30.3 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.

1.30.4 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 personnel with a minimum qualification for acceptance to the Institution of Engineering and Mining Surveyors, Australia or equivalent.

1.30.5 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.

1.30.6 Testing

1.30.6.1 *Limits of Work to be Tested*

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

1.30.6.2 *Test Methods*

The tests methods shall be as stipulated in these Specifications.

1.30.7 Measurement and Test Equipment

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

1.30.8 Records and Reporting

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

Manufacturers' and suppliers' certificates shall enable a clear trace of items from source to the location within the Works.

1.30.9 Payment for Quality Assurance and Testing

The cost of traceability, testing and measurement to the extent required by these Specifications shall be borne by the Contractor.

The Principal shall pay for all Conformance Quality Control testing as stipulated in these Specifications. Any repeat Conformance Quality Control testing due to material replacement shall be borne by the Contractor.

1.31 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;
- Landfill cell layout including:
 - Perimeter bund positions;
 - Anchor trench positions
 - Top of HDPE liner position;
 - Top of leachate drainage aggregate layer, including thickening over leachate pipes;
 - Leachate pipe positions – pipe crown (collection, delivery and extraction lines), including demonstrating that the aggregate thickening over the pipes are in the correct location, ie. directly above the leachate pipes;
 - Leachate sump position – horizontal portion of the sump;
 - Leachate sump position – box shutter position;
 - Leachate sump position – exposed concrete portion;
 - Leachate extraction point 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.