

Table of Contents

1	SECTION 1: HDPE GEOMEMBRANE PARTICULAR SPECIFICATIONS.....	4
1.1	Introduction	4
1.2	References	6
1.3	Submittals	6
1.4	Quality Control	8
1.5	Delivery, Storage and Handling	9
1.6	Project Conditions	9
1.7	Material Warranty	9
1.8	Geomembrane Installation Warranty	9
1.9	Geomembrane Pre-Construction Meeting	10
1.10	GEOMEMBRANE PRODUCT	11
1.11	EXECUTION	12
1.12	CONFORMANCE TESTING OF GEOMEMBRANE	21
1.13	SAFETY PRECAUTIONS	22
2	SECTION 2: GEOSYNTHETIC CLAY LINER (GCL) PARTICULAR SPECIFICATIONS	23
2.1	INTRODUCTION	23
2.2	GCL PRODUCT	29
2.3	EXECUTION	31
	END OF SECTION 2: PARTICULAR SPECIFICATIONS FOR GCL.....	33



3	SECTION 3: HDPE GEONET PARTICULAR SPECIFICATIONS.....	34
3.1	INTRODUCTION	34
3.2	GEONET PRODUCT	38
3.3	CONFORMANCE AND TESTING	39
3.4	EXECUTION	40
3.5	SAFETY PRECAUTIONS	42
4	SECTION 4: GEOGRID GEOCOMPOSITE PARTICULAR SPECIFICATIONS	43
4.1	INTRODUCTION	43
4.2	GEOGRID PRODUCT	47
4.3	CONFORMANCE AND TESTING	48
4.4	EXECUTION	50
4.5	SAFETY PRECAUTIONS	51
5	SECTION 5: GEOTEXTILE PARTICULAR SPECIFICATIONS.....	53
5.1	INTRODUCTION	53
5.2	GEOTEXTILE PRODUCT	60
5.3	CONFORMANCE AND TESTING	61
5.4	EXECUTION	62
5.5	SAFETY PRECAUTIONS	65



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SECTION 1: HDPE GEOMEMBRANE PARTICULAR SPECIFICATIONS

1.1 Introduction

The contractor shall furnish all labor, materials, tools, supervisions, transportations, and installation equipment necessary for installation of the specified geomembranes as per the locations shown on the construction drawings. The Materials shall be installed in accordance to approved QC procedures, in accordance to this specification and to the satisfaction of RAH The materials supplied for this project shall comply with the specifications described in this document.

If the material does not meet project specifications it shall be removed from the work area at the expense of the Contractor

1.1.1 Requirements

- (1) This specification includes furnishing and installing HDPE geomembranes with a formulated sheet density of 0.94 g/cc or greater.
- (2) There are two methods usually used to manufacture HDPE geomembrane, flat sheet extrusion and the blown sheet extrusion methods. For this project the materials shall be manufactured using flat extrusion methods in order to ensure minimum variations in the sheet thickness, and have less sheet waves and movement during installation and soil placement as the sheet temperature changes and to have no fold lines in the material.
- (3) The geomembrane material shall be homogeneous, made from virgin polyethylene co-monomer resin entirely free of plasticisers or other filler materials plus a master batch containing P-Carbon Black to achieve the values given below and free from blemishes
- (4) The High Density Polyethylene (HDPE) geomembrane sheet to be used along the landfill cell floor and slopes and in the evaporation ponds shall have a minimum thickness of 2.0mm and shall not exceed 2.5mm thickness for the smooth and structured geomembrane sheets. Smooth geomembrane shall be installed along the floor of the landfill cell and structured along the slope. Liners with thickness less than 2.0mm will be rejected. no single measurement taken from anywhere within any roll shall be less than 2.0 mm. samples taken from random roles delivered to site will be sent for third party testing to confirm the minimum thickness, density and melt flow index. If one of the samples fails the thickness requirements, the entire materials will be rejected from the site and shall be replaced by the contractor with materials confirming to the minimum thickness requirements.
- (5) During the manufacturing of the liner, the following parameters shall be tested in the laboratories at the factory where the liner is produced: thickness, density, width carbon black content, and melt flow rate,

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- (6) The smooth geomembrane sheet width shall be greater than 7 m in order to minimize the number of seams. The structured surfaced geomembrane shall be greater than 5 m. The structure of the non-smooth geomembrane shall be made out of the same resin as the base geomembrane. The overlapping and welding area shall be marked with a line to assure an adequate size of overlap and shall be smooth with no structuring or other surface treatment. The sheet overlapping and welding area shall be marked with a coloured line for minimum overlap requirements to assure proper overlap of sheets during the welding.

(7) Physical and Mechanical Properties

Table 1A: HDPE Smooth Geomembrane Specifications

Properties	Test Method	Unit	Value	Value
Minimum Thickness	ASTM D 5199	mm	1.5	2.0
Minimum Lowest individual thickness value	ASTM D 5199		1.45	2.0
Multi axial elongation	ASTM D 5617	%	≥15	≥15
Puncture Resistance	ASTM D	N	480-500	680-750
Carbon Black Content	ASTM D 1603	%	2.0± 0.2	2.0± 0.2
Oxidation Induction time	ASTM D 3895	minutes	>100	>100
Carbon Black Distribution	ASTM D 5596	category	1-2	1-2
Stress Crack Resistance	ASTM D 5397	Hours	>350	>350
Oven Aging at 85°C	ASTM D 3895	%	50-55	50-55
Resistance to oxidation	EN 14575		< 13% of original values	< 13% of original values
Reduction of tensile strength and elongation				
Permeability of liquid	EN 14159	m ³ /m ² *d	< 1 E-6	< 1 E-6

Table 1B HDPE Geomembrane Specifications with structured surfaces both sides

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Properties	Test Method	Unit	Value	Value
Minimum Thickness	ASTM D 5199	mm	1.5	2.0
Minimum individual thickness value	ASTM D 5199		1.45	2.0
Asperity Height	ASTM D 7466	mm	≥ 0.85	≥ 0.85
Dimensional stability (1h/100c)	ASTM D 1204	%	≤2	≤1
Carbon Black Content	ASTM D 1603	%	2.0± 0.2	2.0± 0.2
Standard OIT	ASTM D 3895	minutes	>100	>100
Carbon Black Distribution	ASTM D 5596	category	1-2	1-2
Stress Crack Resistance**	ASTM D 5397	Hours	>350	>350
Oven Aging at 85°C	ASTM D 3895	% retained	50-55	50 - 55
UV Resistance Std OIT	ASTM D 3895	%	50	50
Resistance to oxidation	EN 14575		< 13% of original values	< 13% of original values
Reduction of tensile strength and elongation				
Permeability to liquids	EN 14159	m ³ /(m ² *d)	< 1 E-6	< 1 E-6

1.2 References

1.2.1 Geosynthetic Research Institute (GRI):

- (1) GRI GM 10, the Stress Crack Resistance of HDPE Geomembrane Sheet
- (2) GRI GM 13, Test Properties, Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
- (3) GRI GM 14, Test Frequencies for Destructive Seam Testing Selecting, variable intervals for taking Geomembrane destructive samples using the method of attributes.
- (4) GRI GM 19, Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

1.3 Submittals

1.3.1 Submit the following to the RAH for review and approval, within one week from receiving the Letter of award to expedite shipment and installation of the Geomembrane:

- (1) Manufacturer's Quality Control program manual and material properties sheet, including at a minimum all properties specified in section 1.1, and 1.1.1 above.
- (2) Sample of the materials

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- (3) Documentation of Installer's qualifications, as specified
- A- Submit a list of at least ten (10) completed and ongoing landfill facilities. For each installation, provide: name and type of facility; its location; the date of installation; name and telephone number of contact at the facility; type and thickness of geomembrane and; surface area of the installed geomembrane.
 - B- Submit resumes or qualifications of the Installation Supervisor, Master Seamer and Technicians to be assigned to this project.
 - C- Submit Construction Quality Control Plan (CQC) in accordance to USEPA requirements as described in USEPA technical Guidance document "Quality control for waste Containment Facilities" EPA/600/R-93/182
 - D- Submit the CV of the Quality Control Engineer
- (4) Submit sample Material Warranty and Liner Installation Warranty
- (5) Submit the execution plan
- (6) Submit manpower histogram
- (7) Delivery and installation schedule and milestones
- (8) Method statement and job safety analyses for the day-day installation
- (9) Contingency plan for material delivery and equipment breakdown
- (10) Shop Drawings

1.3.2 Submit copies of shop drawings for RAH's approval within two weeks after obtaining the materials approval. Shop drawings shall show the proposed panel layout identifying seams and details. Seams should generally follow the direction of the slope. Butt seams or roll-end seams should not occur on a slope unless approved by RAH

1.3.3 Placement of geomembrane should not be allowed to proceed until RAH has received and approved the shop drawings.

- (1) Additional Submittals (In-Progress and at Completion)
- A- Manufacturer's warranty
 - B- Geomembrane installation warranty

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- C- Daily written acceptance of subgrade surface
- D- Temperature seaming procedures
- E- Prequalification test seam samples
- F- Field seam non-destructive test results
- G- Field seam destructive test results if required by RAH
- H- Daily field installation quality control reports
- I- Installation record drawing

1.4 Quality Control

1.4.1 Manufacturer's Qualifications:

The manufacturer of geomembrane of the type specified shall have at least 15 years' experience in the manufacture of such geomembrane. In addition, the geomembrane manufacturer shall have manufactured at least 30,000,000 M2 of the specified type of geomembrane or similar product during the last five years.

1.4.2 Installer's Qualifications

- (1) The Installation Company shall be the approved Manufacturer's Installation working under the manufacturer's installation management and technical support the installation company shall demonstrate their technical experience in design and installation of landfill cell soil-geosynthetics-lining system and knowledge of soil and concrete placement on top of the lining system. Installers not meeting the minimum experience requirements will not be allowed at site.
- (2) Installation shall be performed under the direction of a field Installation Engineer who shall be responsible throughout the geomembrane installation, for geomembrane panel layout, seaming, patching, testing, repairs, and all other activities of the Geomembrane including daily documentations and reports. The Field Installation Supervisor shall have installed or supervised the installation and seaming of a minimum of 5 landfills. The Installation Supervisor will be technically interviewed for his knowledge and experience in the design and installation of landfill cell soil-geosynthetics-lining system and knowledge of soil and concrete placement on top of the lining system and must be approved by RAH The bidder shall provide the CV of the Installation Supervisor to assist with the technical evaluation.
- (3) Seaming shall be performed under the direction of a Master Seamer having experience of welding, testing and managing the installation of liners for landfill cells.

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- (4) All seaming, patching, other welding operations, and testing shall be performed by qualified technicians.

1.5 Delivery, Storage and Handling

- (1) Each roll of geomembrane delivered to the site shall be labelled by the manufacturer. The label shall be firmly affixed and shall clearly state the manufacturer's name, product identification, material thickness, roll number, roll dimensions and roll weight.
- (2) Geomembrane shall be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.
- (3) Rolls shall be stored away from high traffic areas. Continuously and uniformly support rolls on a smooth, level prepared surface.

1.6 Project Conditions

Geomembrane should 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 herein. Geomembrane should not be installed during humidity outside the limits specified herein.

1.7 Material Warranty

10-years from the shipping date. The manufacturer has to be in business for a minimum of 10-year in order to accept their 10-year warranty on materials.

1.8 Geomembrane Installation Warranty

- 1.8.1 The Contractor shall guarantee the geomembrane installation against defects in the installation and workmanship for 1 year commencing from the date of final acceptance.**

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1.9 Geomembrane Pre-Construction Meeting

1.9.1 A Geomembrane Pre-Construction Meeting shall be held at the site prior to installation of the geomembrane.

1.9.2 Topics for this meeting shall include:

- (1) Health and Safety
- (2) Lines of authority and communication; resolution of any project document ambiguity
- (3) Methods for documenting, reporting and distributing documents and reports
- (4) Procedures for packaging and storing archive samples.
- (5) Review of time schedule for all installation and testing.
- (6) Review of panel layout and numbering systems for panels and seams including details for marking on geomembrane.
- (7) Procedures and responsibilities for preparation and submission of as-built panel and seam drawings
- (8) Temperature and weather limitations; Installation procedures for adverse weather conditions; Defining acceptable subgrade, geomembrane, or ambient moisture and temperature conditions for working during liner installation
- (9) Subgrade conditions
- (10) Deployment techniques
- (11) Plan for controlling expansion/contraction and wrinkling of the geomembrane
- (12) Covering of the geomembrane and cover soil placement
- (13) Measurement and payment schedules
- (14) Responsibilities of each party

1.9.3 The meeting shall be documented by a person designated at the beginning of the meeting and minutes shall be transmitted to all parties.

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1.10 GEOMEMBRANE PRODUCT

1.10.1 Manufacturers Quality Control

- (1) The manufacturer's geomembrane quality control certifications, including results of quality control testing of the products (Thickness, MFR, Density, Carbon Black), shall be supplied to the RAH Representative to verify that the materials supplied for the project are in compliance with all product specifications in this Section. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information. Provision shall be made in the contractor price to allow for RAH 2 staff to visit the liner Manufacturer(s) to inspect and approve the manufacturing process and manufacturing quality control and quality assurance testing program and laboratory.
- (2) The Manufacturer shall provide Certification that the geomembrane and welding rod supplied for the project are made from the same material type and are compatible.

1.10.2 Resin Control

Every truck (about 24 tons of resin) of resin is sampled immediately at arrival at factory. The lab-technicians take the sample when the truck arrives and start to test the following parameters:

When these tests are finished, the test results are compared to the manufacturer's specifications. If the material meets the specification, it is transported to the raw material stock. If only one test does not meet the specification, the material shall be rejected and returned to the supplier.

1.10.3 Geomembrane manufacturer Quality Control

1.10.4 Production Control

The quality control of the geomembrane shall be continued during the production of the membranes. Special test plans for the production staff are followed.

Thickness: every roll

Width once per shift

Width and marking for overlap once per shift

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1.10.5 Laboratory Control

At the minimum frequency given below, a strip of the geomembrane shall be taken over the whole width to the laboratory for further QA-Testing. The lab technicians cut the samples from this strip with a special die to ensure uniformity according to the standards. The following tests shall be carried out.

Thickness: every roll

Tensile strength, elongation, and dimensional stability, once per shift

Carbon black contents, dispersion, and density, MFR, and puncture resistance, once per day

The test laboratory test results shall be documented in the manufacturer's electronic data management system. The retained samples of the geomembranes shall be archived for number of years required by GRI requirements. Any roll not meeting the specifications and the following roll shall be rejected.

1.11 EXECUTION

1.11.1 Subgrade Preparation

- (1) The subgrade shall be prepared in accordance with the project specifications. The geomembrane subgrade shall be uniform and free of sharp or angular objects that may damage the geomembrane prior to installation of the geomembrane.
- (2) The Contractor and RAH representative shall inspect the surface to be covered with the geomembrane on each day's operations prior to placement of geomembrane to verify suitability.
- (3) The Contractor shall provide daily written acceptance for the surface to be covered by the geomembrane in that day's operations. The surface shall be maintained during geomembrane installation, to ensure subgrade suitability.
- (4) All damaged surface liner to be covered by the geomembrane shall be repaired prior to placement of the geomembrane. All repairs shall be approved by RAH Representative.

1.11.2 Geomembrane Placement

- (1) No geomembrane shall be deployed until the applicable certifications and quality control certificates listed in the subsections above of this Section are submitted to and approved by RAH within the timeframe specified in the Contract Documents. If the material does not meet project specifications it shall be removed from the work area at the expense of the Contractor.

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- (2) The geomembrane shall be installed to the limits shown on the project approved drawings and essentially as shown on approved panel layout drawings.
- (3) No geomembrane material shall be unrolled and deployed if the sheet temperature taken at the surface of the roll is greater than 65 degrees centigrade unless otherwise approved by RAH The specified minimum temperature for material deployment may be adjusted based on manufacturer recommendations and the approval of RAH The Temperature limitations should be defined in the preconstruction meeting.
- (4) Only the quantity of geomembrane that shall be anchored and seamed together in one day should be deployed.
- (5) The humidity allowed during the fusion welding is 90% and 83% for extrusion welding. The specified Maximum humidity for material welding may be adjusted by RAH based on site specific conditions and if field trials show good welds at higher humidity values, then welding shall continue to take place as approved by RAH Representative.
- (6) The protective plastic film strips along the bonded edges of the sheet shall only be removed as the welding proceeds.
- (7) No vehicular traffic shall travel on the geomembrane other than an approved low ground pressure Vehicle or equivalent and as approved by RAH
- (8) Sand bags shall be used as necessary to temporarily hold the geomembrane material in position under the foreseeable and reasonably - expected wind conditions. Sand bag material shall be sufficiently close- knit to prevent soil fines from working through the bags and discharging on the geomembrane.
- (9) Damaged panels or portions of the damaged panels which have been rejected shall be marked and their removal from the work area recorded.
- (10) The geomembrane shall not be allowed to "bridge over" voids. The geomembrane shall rest in intimate contact with the GCL and underlying materials.
- (11) Wrinkles caused by panel placement or thermal expansion should be minimized in.
- (12) 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 minimized. Seams shall not be located at low points in the subgrade unless geometry requires seaming at such locations and if approved by RAH
- (13) 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 100-mm.

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1.11.3 Seaming Procedures

- (1) Cold weather installations should follow guidelines as outlined in GRI GM9.
- (2) No geomembrane material shall be seamed if the sheet temperature taken at the surface of the roll is greater than 65 degrees centigrade unless otherwise approved by RAH and unless the following conditions are complied with: .
- (3) Seaming of the geomembrane at material surface temperatures above 65 degrees centigrade is allowed if the Contractor can demonstrate to RAH using pre-qualification test seams, that field seams comply with the project specifications, the safety of the crew is ensured, and geomembrane material can be fabricated (i.e. pipe boots, penetrations, repairs. etc.) at this temperatures. This approval May be based on recommendations by the manufacturer and on a field demonstration by the Contractor using prequalification test seams to demonstrate that seams comply with the specification.
- (4) The Contractor shall submit to RAH for approval, detailed procedures for seaming at this temperatures
 - A- 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 pipe penetrations, patches, repairs and short (less than a roll width) runs of seams.
 - B- Fish mouths or excessive wrinkles at the seam overlaps shall be minimized and when necessary cut along the ridge of the wrinkles back into the panel so as to effect a flat overlap. The cut shall be terminated with a keyhole cut (nominal 10 mm diameter hole) so as to minimize crack/tear propagation. The overlay shall subsequently be seamed. The key hole 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.

1.11.4 Pipe and Structure Penetration Sealing System

- (1) Provide penetration sealing system as shown in the Project Drawings.
- (2) Penetrations shall be constructed from the base geomembrane material, prefabricated boots and accessories as shown on the Project Drawings. The prefabricated or field fabricated assembly shall be field welded to the geomembrane as shown on the Project Drawings so as to prevent leakage. This assembly shall be tested as outlined in the subsections below. Alternatively, where field non-destructive testing cannot be performed, attachments shall be field spark tested by standard holiday leak detectors in accordance with ASTM 6365
- (3) Spark testing should be done in areas where both air pressure testing and vacuum testing is not possible. Equipment for Spark testing shall be comprised of but not limited to: A hand held holiday spark tester and conductive wand that generates a high voltage. The testing activities

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shall be performed by the Contractor by placing an electrically conductive tape or wire beneath the seam prior to welding. A trial seam containing a non-welded segment shall be subject to a calibration test to ensure that such a defect (non-welded segment) shall be identified under the planned machine settings and procedures. Upon completion of the weld, enable the spark tester and hold approximately 25mm above the weld moving slowly over the entire length of the weld in accordance with ASTM 6365. If there is no spark the weld is considered to be leak free if spark indicates a hole in the seam. The faulty area shall be located, repaired and retested by the Contractor. Care should be taken if flammable gases are present in the area to be tested.

1.11.5 Field Quality Control

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

(1) Prequalification Test Seams

- A- Test seams shall prepare and tested by the Contractor to verify that seaming parameters (speed, temperature and pressure of welding equipment) are adequate.
- B- Test seams shall be made by each welding technician and tested in accordance with ASTM D 4437 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 2.0 meters long for fusion welding and 1 meter long for extrusion welding with the seam centered lengthwise. At a minimum, tests seams should be made by each technician 1 time every 4–6 hours; additional tests may be required with changes in environmental conditions.
- C- Two 25 mm wide specimens shall be die-cut by the Contractor from each end of the test seam. These specimens shall be tested by the Contractor using a field tensiometer testing both tracks for peel strength and also for shear strength. Each specimen should fail in the parent material and not in the weld, “Film Tear Bond”(F.T.D. failure). Seam separation equal to or greater than 25% of the track width shall be considered a failing test. Other testing method can only be used if approved by RAH
- D- 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.
- E- A sample from each test seam shall be labeled. 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 RAH for archiving.

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(2) Field Seam Non-destructive Testing

- A- All field seams shall be non-destructively tested by the 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 RAH
- B- Testing should be done as the seaming work progresses, not at the completion of all field seaming, unless agreed to in advance by the RAH All defects found during testing shall be numbered and marked immediately after detection. All defects found should be repaired, retested and remarked to indicate acceptable completion of the repair.
- C- Non-destructive testing shall be performed using vacuum box, air pressure or spark testing equipment.
- D- Non-destructive tests shall be performed by experienced technicians familiar with the specified test methods. The Contractor shall demonstrate to the RAH all test methods to verify the test procedures are valid.
- E- Extrusion seams shall be vacuum box tested by the Contractor in accordance with ASTM D 4437 and ASTM D 5641 with the following equipment and procedures:
 - (i) 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, port hole 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 paint brush or mop; and a soapy solution.
 - (ii) The vacuum pump shall be charged and the tank pressure adjusted to approximately 35 kPa (5 psi).
 - (iii) The Contractor shall create a leak tight seal between the gasket and geomembrane interface by wetting a strip of geomembrane approximately 0.3m (12 in) by 1.2m (48 in) (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 Contractor shall then close the bleed valve, open the vacuum valve, maintain initial pressure of approximately 35 kPa (5 psi) for approximately 5 seconds. The geomembrane should 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 depressurized and moved over the next adjoining area with an appropriate overlap and the process repeated.

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- (iv) All areas where soap bubbles appear shall be marked, repaired and then retested.
- (v) At locations where seams cannot be non-destructively tested, such as pipe penetrations, alternate non-destructive spark testing (as outlined in section 1.11.4(3)) or equivalent should be substituted.
- (vi) 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.

F- Double Fusion seams with an enclosed channel shall be air pressure tested by the Contractor in accordance with ASTM D 5820 and ASTM D 4437 and the following equipment and procedures:

- (i) 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 psi), mounted on a cushion to protect the geomembrane; and a manometer equipped with a sharp hollow needle or other approved pressure feed device.
- (ii) The Testing activities shall be performed by the 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 (30 psi), and the valve closed,. Allow 2 minutes for the injected air to come to equilibrium in the channel, and sustain pressure for 5 minutes. If pressure loss does not exceed 28 kPa (4 psi) after this five minute period the seam shall be considered leak tight. Release pressure from the opposite end verifying pressure drop on needle to ensure testing of the entire seam. The needle or other approved pressure feed device shall be removed and the feed hole sealed.
- (iii) If loss of pressure exceeds 28 kPa (4 psi) during the testing period or pressure does not stabilize, the faulty area shall be located, repaired and retested by the Contractor.
- (iv) Results of the pressure testing shall be recorded on the liner at the seam tested and on a pressure testing record.

(3) Destructive Field Seam Testing

- A- One destructive test sample per 150 linear m (500 linear ft) seam length or another predetermined length in accordance with GRI GM 14 shall be taken by the Contractor from Business Use



- a location specified by RAH Representative. The 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 Contractor as directed by the RAH as seaming progresses.
- B- All field samples shall be marked with their sample number and seam number. The sample number, date, time, location, and seam number shall be recorded. The Contractor shall repair all holes in the geomembrane resulting from obtaining the seam samples. All patches shall be vacuum box tested or spark tested. 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.
- C- The destructive sample size shall be 300 mm (12 in) wide by 1 m (36 in) long with the seam centered lengthwise. The sample shall be cut into three equal sections and distributed as follows: one section given to RAH Representative as an archive sample; one section given to RAH Representative for laboratory testing as specified in paragraph E- below; and one section retained by the Contractor for field testing as specified in paragraph 4 below.
- D- For field testing, the Contractor shall cut 10 identical 25 mm (1 in) wide replicate specimens from his sample. The Contractor shall test five specimens for seam shear strength and five for peel strength. Peel tests shall be performed on both inside and outside weld tracks. To be acceptable, 4 of 5 test specimens shall pass the stated criteria in section 2.02 with less than 25% separation. If 4 of 5 specimens pass, the sample qualifies for testing by the testing laboratory if required.
- E- If independent seam testing is required by RAH it shall be conducted in accordance with ASTM 5820 or ASTM D4437 or GRI GM 6.
- F- Reports of the results of examinations and testing shall be prepared and submitted to RAH Representative.
- G- 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 Contractor at locations indicated by RAH Representative; typically 3 m (10 feet) 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 non-adequate seams and all seams represented by the destructive test location shall be repaired with a cap-strip extrusion welded to all sides of the capped area. All cap-strip seams shall be non-destructively vacuum box tested until adequacy of the seams is achieved. Cap strip seams exceeding 50 M in length (150 FT) shall be destructively tested.

(4) Identification of Defects

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- A- Panels and seams shall be inspected by the Contractor and RAH during and after panel deployment to identify all defects, including holes, blisters, and signs of contamination by foreign matter.

(5) 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 Section 1.11.5 (2) Each location which fails non-destructive testing shall be marked, numbered, measured and posted on the daily "installation" drawings and subsequently repaired.

- A- If a destructive sample fails the field or laboratory test, the Contractor shall repair the seam between the two nearest passed locations on both sides of the failed destructive sample location.
- B- Defective seams, tears or holes shall be repaired by reseaming or applying an extrusion welded cap strip.
- C- Reseaming may consist of either:
- (i) Removing the defective weld area and rewelding the parent material using the original welding equipment; or
- (ii) Reseaming by extrusion welding along the overlap at the outside seam edge left by the fusion welding process
- D- 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 (6 in) beyond all edges of the defects.
- E- All repairs shall be measured, located and recorded.

(6) Verification of Repairs on Seams:

Each repair shall be non-destructively tested using either vacuum box or spark testing 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 retested until a passing test results. The number, date, location, technician and test outcome of each patch shall be recorded.

(7) Daily Field Installation Reports:

- (8) At the beginning of each day's work, the Installer shall provide RAH Representative with daily reports for all work accomplished on the previous work day. Reports shall include the following:

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- A- Total amount and location of geomembrane placed;
- B- Total length and location of seams completed, name of technicians doing seaming and welding unit numbers;
- C- Drawings of the previous day's installed geomembrane showing panel numbers, seam numbers and locations of non-destructive and destructive testing;
- D- Results of pre-qualification test seams;
- E- Results of non-destructive testing; and
- F- Results of vacuum testing of repairs

(9) Destructive test results shall be reported prior to covering of liner or within 48 hours.

1.11.6 Liner Acceptance

- (1) Geomembrane liner shall be accepted by RAH when:
 - A- The entire installation is finished or an agreed upon subsection of the installation is finished;
 - B- All Installer's QC documentation is completed and submitted to RAH
 - C- Verification of the adequacy of all field seams and repairs and associated geomembrane testing is complete.

1.11.7 Anchorage

As directed by the project drawings and specifications, the end of the geomembrane roll shall be placed in the anchor trench at the top of the slope. Loose soil should be removed from the floor of the trench (top of GCL or geotextile laid in the trench).

1.11.8 Disposal of Scrap Materials

On completion of installation, the Contractor shall dispose of all trash and scrap material in a location approved by the RAH, remove equipment used in connection with the work herein, and shall leave the premises in a neat acceptable manner. No scrap material shall be allowed to remain on the geomembrane surface.

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1.12 CONFORMANCE TESTING OF GEOMEMBRANE

Upon, or prior to, delivery of the rolls of geomembrane, the Contractor shall verify that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to verify conformance with the test methods and values presented in in this particular specifications. Samples shall be taken and tested at a minimum frequency of one sample per 10,000 m² or one sample per lot, whichever results in a greater frequency. This requirement may be waived by RAH provided that sufficient manufacturer quality control testing is presented and the materials are in full compliance with the physical and mechanical properties presented in subsection section 1.1.1 above and the manufacturer has been in business for more than 20 years.

1.12.1 Sample Collection

Using packing list provided by the manufacturer or a sequential inventory list made at site, rolls shall be selected for sampling at a minimum frequency of one sample per 50,000 m² of material. If the material is shipped in identifiable lots or manufacturing runs, sample selection should be adjusted to assure that the minimum frequency is met and that each different lot or manufacturing run is represented by at least one sample.

Samples shall be taken across the entire width of the roll and should not include the first 1 m of the roll if it is damaged. Unless otherwise specified, samples shall be 1 m long by the roll width. The Contractor shall mark the machine direction on the samples with an arrow. Conformance testing shall be conducted in accordance with specification.

1.12.2 Test Results

The results of the conformance testing shall be evaluated by RAH in accordance to the Following procedure:

- (1) If the minimum test values for the sample meet the requirements presented in specification and the Manufacturer's guaranteed minimum values, the sample passes.
- (2) If the minimum test value for the sample does not meet one or more of the required values, additional evaluation procedures may be implemented by RAH Additional tests required for further evaluation shall be at the expense of the supplier. If the materials do not meet the minimum requirements, the contractor is responsible for the removal of the materials from the site and replacement with materials meeting the specifications.

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1.13 SAFETY PRECAUTIONS

- (1) Personnel working on the geomembrane shall not smoke or wear damaging shoes.
- (2) The surface of the geomembrane shall not be used as a working area for sorting tools and supplies. If needed, a protective cover shall be spread out as a working surface.

END OF SECTION 2: PARTICULAR SPECIFICATIONS FOR HDPE
GEOMEMBRANES

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SECTION 2: GEOSYNTHETIC CLAY LINER (GCL) PARTICULAR SPECIFICATIONS

2.1 INTRODUCTION

The Contractor shall furnish all labor, materials, tools, supervisions, transportations, and installation equipment necessary for installation of the specified GCL as per the locations shown on the drawings. The Materials shall be installed in accordance to approved QC procedures in accordance to this specification and to the satisfaction of RAH Representative. The materials supplied for this project shall comply with the specifications described in this document. If the material does not meet project specifications it shall be removed from the work area at the expense of the Contractor

2.1.1 Definitions

For the purposes of this specification guideline, the following terms are defined below:

- (1) Geosynthetic Clay Liner (GCL): A shear strength transmitting geosynthetic clay liner, continuously needled-punched through all components with additional bentonite powder impregnated into the 50-cm overlapping area on both longitudinal sides of the cover geotextile layer and the 30-cm longitudinal overlapping area is marked on the bottom sides.
- (2) Geotextile: Any permeable geosynthetic comprised solely of textiles.
- (3) Minimum Average Roll Value: For geosynthetics, the value calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.
- (4) Overlap: Where two adjacent GCL panels contact, the distance measuring perpendicular from the overlying edge of one panel to the underlying edge of the other.
- (5) Typical Value: The mean value calculated from documented manufacturing quality control test results for a defined population obtained from one test method associated with one specific property.

2.1.2 Requirements

This specification covers the technical requirements for the furnishing and installation of the geosynthetic clay liner described herein. All materials used shall meet the requirements of this specification, and all work shall be performed in accordance with the procedures provided herein and the contract drawings.

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The geosynthetic clay liner (GCL) shall use two geotextile layers to encapsulate a layer of natural sodium bentonite by continuously needle-punched through all components in order for the needle-punched fibers to transmit shear forces through the bentonite core with additional bentonite powder impregnated into the 50-cm overlapping area on both longitudinal sides of the cover geotextile layer and the 30-cm longitudinal overlapping area is marked on the bottom sides.

2.1.3 Physical and Mechanical Properties

Table 1: GCL Specifications

MATERIAL PROPERTY	TEST METHOD	Unit	REQUIRED VALUES
Geotextile cover layer Mass per unit area	EN ISO 9864	g/m ²	220
Geotextile carrier layer Mass per unit area	EN ISO 9864	g/m ²	110
Bentonite Swell Index	ASTM D 5890	ml/2g.	22-24
Bentonite Fluid Loss	ASTM D 5891	ml max.	18-20
Bentonite Water content	ISO 1165	%	8-10
Bentonite Mass/Area	ASTM D 5993 EN 14196	g/m ²	3,670
GCL Thickness	EN ISO 9863-1	mm	6
GCL Tensile Strength md/cmd	ASTM D 4595 EN ISO 10319	KN/m	12/12
GCL Elongation at Break	ASTM D 4595 EN ISO 10319	%	10/6
GCL Peel Strength	ASTM D 6496	N/10cm; N/m	≥60; ≥360
GCL Hydraulic Conductivity	ASTM D 5887 DIN 18130	m/s	2 x 10 ⁻¹¹ cm/sec max
Roll Dimensions		m x m	4.85 x 50

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2.1.4 References

- (1) ASTM D 5261 (1992; R 2003) Measuring Mass Per Unit Area of Geotextiles
- (2) ASTM D 5887 (2008) Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter
- (3) ASTM D 5888 (2006) Storage and Handling of Geosynthetic Clay Liners
- (4) ASTM D 5889 (1997; R 2003) Quality Control of Geosynthetic Clay Liners
- (5) ASTM D 5890 (2006) Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
- (6) ASTM D 5891 (2002) Fluid Loss of Clay Component of Geosynthetic Clay Liners
- (7) ASTM D 5993 (1999; R 2004) Measuring Mass Per Unit of Geosynthetic Clay Liners
- (8) ASTM D 6072 (2008) Obtaining Samples of Geosynthetic Clay Liners
- (9) ASTM D 6243 (2008) Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method
- (10) ASTM D 6496 (2004a) Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners
- (11) ASTM D 6768 (2004) Tensile Strength of Geosynthetic Clay Liners
- (12) ASTM D 792 (2008) Density and Specific Gravity

2.1.5 Submittals

- (1) Submit the following to RAH for review and approval, within one week from receiving the Letter of award to expedite shipment or installation of the GCL:
 - A- Manufacturer's Quality Control program manual and material properties sheet, including at a minimum all properties specified in section 2.02, and 2.02 above.
 - B- Sample of the materials
 - C- Documentation of Installer's qualifications, as specified
 - (i) Submit a list of projects including: name and type of facility; its location; the date of installation; name and telephone number of contact at the facility; type of GCL and; surface area of the installed GCL.
 - (ii) Submit the Quality Control Program. Submit Construction Quality Control Plan (CQC) in accordance to USEPA requirements as described in USEPA technical Guidance document "Quality control for waste Containment Facilities" EPA/600/R-93/182

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- (iii) Submit the CV of the Quality Control Engineer
 - D- Submit sample Material Warranty and Liner Installation Warranty
 - E- Submit the execution plan
 - F- Delivery and installation schedule and milestones
 - G- Method statement and job safety analyses for the day-day installation
 - H- Contingency plan for material delivery and equipment breakdown
- (2) Shop Drawings
 - A- Submit copies of shop drawings for RAH's approval within two weeks after obtaining the materials approval. Shop drawings shall show the proposed panel layout identifying seams and details. Seams should generally follow the direction of the slope. Butt seams or roll-end seams should not occur on a slope unless approved by RAH. Butt seams on a slope, if allowed, should be staggered.
 - B- Placement of GCL should not be allowed to proceed until RAH has received and approved the shop drawings.
- (3) Additional Submittals (In-Progress and at Completion)
 - A- Manufacturer's warranty
 - B- GCL installation warranty
 - C- Daily written acceptance of subgrade surface
 - D- Daily field installation reports
 - E- Installation record and as built drawings

2.1.6 Quality Control

(1) Manufacturer's Qualifications:

The manufacturer of GCL of the type specified shall have at least five years' experience in the manufacture of such GCL.

(2) Installer's Qualifications

- A- The Contractor shall be approved Manufacturer's Installer and also approved by RAH's Representative to install the GCL.

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- B- The Contractor shall have experience in the installation of the specified GCL.
- C- Installation shall be performed under the direction of a field Installation Quality Control Engineer who shall be responsible throughout the GCL installation, for GCL panel layout, seaming, patching, repairs, and all other activities of the GCL including daily documentations and reports.
- D- All seaming, patching, shall be performed by qualified technicians employed by the GCL Installer.

2.1.7 Shipping and Handling

- (1) The manufacturer assumes responsibility for initial loading the GCL. Shipping shall be the responsibility of the Contractor. Unloading, on-site handling and storage of the GCL are the responsibility of the Contractor.
- (2) A visual inspection of each roll should be made during unloading to identify if any packaging has been damaged. Rolls with damaged packaging should be marked and set aside for further inspection. The packaging should be repaired prior to being placed in storage.
- (3) The party responsible for unloading the GCL should contact the Manufacturer prior to shipment to ascertain the appropriateness of the proposed unloading methods and equipment.

2.1.8 Storage

- (1) Storage of the GCL rolls shall be the responsibility of the installer. A dedicated storage area shall be selected at the job site that is away from high traffic areas and is level, dry and well drained.
- (2) Rolls should be stored in a manner that prevents sliding or rolling from the stacks and may be accomplished by the use of chock blocks. Rolls should be stacked at a height no higher than that at which the lifting apparatus can be safely handled (typically no higher than four).
- (3) All stored GCL materials and the accessory bentonite shall be covered with a plastic sheet or tarpaulin until their installation.
- (4) The integrity and legibility of the labels shall be preserved during storage.

2.1.9 Project Conditions

- (1) GCL should not be installed in the presence of standing water, while precipitation is occurring,

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2.1.10 Manufacturer Material Warranty

10-years from the shipping date.

2.1.11 GCL Installation Warranty

- (1) The Contractor shall guarantee the GCL installation against defects in the installation and workmanship for 1 year commencing from the date of final acceptance.

2.1.12 GCL Pre-Construction Meeting

- (1) GCL Pre-Construction Meeting shall be held at the site prior to installation of the GCL. At a minimum, the meeting shall be attended by the Contractor, RAH Representative and the Earthwork Contractor.
- (2) Topics for this meeting shall include:
 - A- Health and Safety
 - B- Lines of authority and communication; Resolution of any project document ambiguity
 - C- Methods for documenting, reporting and distributing documents and reports
 - D- Procedures for packaging and storing archive samples.
 - E- Review of time schedule for all installation and testing.
 - F- Review of panel layout and numbering systems for panels and seams.
 - G- Procedures and responsibilities for preparation and submission of as-built panel and seam drawings
 - H- Subgrade conditions
 - I- Deployment techniques
 - J- Measurement and payment schedules
 - K- Responsibilities of each party
- (3) The meeting shall be documented by a person designated at the beginning of the meeting and minutes shall be transmitted to all parties.

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2.2 GCL PRODUCT

2.2.1 Manufacturers Quality Control

- (1) The test methods and frequencies used by the manufacturer for quality control/quality assurance of the specified GCL prior to delivery, shall be in accordance with EN 150 and ASTM standards.
- (2) The GCL manufacturer's quality control certifications, including results of quality control testing of the products, as specified, shall be supplied to the RAH Representative to verify that the materials supplied for the project are in compliance with all product specifications in this section. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.
- (3) Bentonite:

The Manufacturing QA/QC Manual SHALL describes the sources of the raw materials utilized in the GCL as well as the specific procedures carried out to monitor the quality of these components. It shall allow for verification of critical quality parameters prior to the component's use in finished GCL product as well as monitoring the quality of the GCL finished product itself.

- (4) Suppliers

The bentonite producers are responsible for all aspects of the processing including selective mining, processing to the correct gradation, adherence to internal quality control procedures and loading into silos for transportation to the GCL manufacturing facility.

- (5) Bentonite Supplier Quality Control Parameters

The supplier shall be required to certify as well as provide test data in the form of a Certificate of Analysis (COA) for each shipment sent the GCL manufacturer. Data required on the COA includes the base clay parameters.

- (6) Bentonite Supplier Certificates of Analysis

QA procedures for bentonite shipped to the plant shall begin with collecting and maintaining Certificates of Analysis (COA's) issued to the manufacturer for each shipment while the associated bentonite lot numbers are recorded in the operations log.

- (7) Manufacturer's Quality Assurance Sampling Protocol & Procedures

As a minimum, samples shall be taken from every 50 ton lot of bentonite. This sampling/testing frequency equates to almost one test for every 10,000 m² as there are approximately five kg of bentonite per m² of GCL. The primary quality parameters tested for the bentonite are Water Content, Swell Index.

- (8) Carrier Woven Geotextile

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The woven geotextile is the primary support for the different GCL products. The woven play a role in providing dimensional stability. A thorough trial of every woven geotextile contemplated for use is completed prior to its acceptance for the use in the finished GCL products. Only those woven products which consistently meet or exceed the Approved and certified manufacturer's Quality program shall be used.

(9) Supplier Certificates of Analysis

The manufacturer shall maintain all manufacturer certifications on file, stating that the products meet the particular specifications. Each roll in the lot shall be labeled with its lot and roll number, and the date and time at which a roll is placed into GCL production is recorded on the daily operating log. This procedure allows the usage of the woven Geotextile to be tracked such that its lot and roll number can be directly determined from the corresponding GCL roll number.

(10) Sampling Protocol & Procedures

Although the overall quality of the woven geotextile is assured through its manufacturer, additional testing shall be conducted by the manufacturer on woven geotextiles. Full roll-width samples shall be obtained and tested for those properties listed in the manufacturer's QC-Testing Frequency document. This testing provides a means for confirming or more accurately determining the specifications attributed to the woven geotextile by its manufacturer.

if the manufacturer's test results indicate that the woven geotextile does not meet its quality criteria, the roll from the suspect lot is evaluated in accordance with manufacturer's approved quality control procedures.

(11) "Cap" Nonwoven Geotextile

Similar procedures as described above shall apply to the "Cap" (also known as "cover") nonwoven needle-punched geotextile

(12) Finished Geosynthetic Clay Liner

A- Lot Size and Determination

On each GCL roll a label with identification values shall be fixed. The following identification shall be printed on the label:

- Unique Roll Number
- Product Name / Type
- Size of the roll (width x length)
- Article Number
- Raw Materials
- Mass per unit Area

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B- Post Production Quality Assurance

A finished GCL sample is cut across the roll width, approx. 500 mm by roll width. This sample shall be immediately sent to the quality assurance laboratory for finished product testing.

C- Evaluation of Results

Finished GCL samples shall be tested using the frequencies and procedures listed in the manufacturer's approved and certified quality control and quality assurance manual. All data shall be recorded and compared to established order specifications. If materials do not meet the required average values and/or the project specifications, the manufacturing personnel shall be notified to make the appropriate adjustments. Only products meeting the standard values and project specifications shall be approved for shipment to the corresponding project.

D- Reporting

All rolls supplied for this project shall be provided a Manufacturing Quality Assurance document for the finished GCL. This report identifies the standards on which the manufacturer's approval is based along with the actual test results demonstrated by the material. Each report is reviewed by quality assurance personnel, stamped, and initiated by the laboratory technician.

E- Finished Roll Specifications

GCL material MQC specifications shall be listed in the manufacturer's data sheets.

F- Packaging and Labeling

Each roll of GCL material shall be packaged in a polyethylene sleeve capable of preventing undue moisture from contacting the enclosed GCL product.

2.3 EXECUTION

2.3.1 Subgrade Preparation

- (1) The subgrade shall be prepared in accordance with the project specifications.
- (2) The Contractor and RAH shall inspect the surface to be covered with the GCL on each day's operations prior to placement of GCL to verify suitability.
- (3) The Contractor and RAH Representative shall provide daily written acceptance for the surface to be covered by the GCL in that day's operations.

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2.3.2 GCL Installation

As GCL rolls are selected for deployment, the roll labels should be removed and recorded by the installer, along with any other pertinent information. The layout and sequence of panel placement is determined by direction of water run-off. Panels are laid out according to the previously approved panel layout drawings.

Generally, the installation is started at the up-wind side and at the highest elevation so that any rainfall runs off the lower part of the impoundment, this prevents water from hydrating the GCL. When in position, panels are checked for any physical damage. All GCL rolls should be installed in a relaxed condition, and be free of wrinkles and folds.

Rolls of GCL material shall be unrolled using a front-end loader or other handling equipment approved by RAH. Panels on slopes shall be placed so that the seam runs parallel to the direction on the slope. Flat areas are laid in no particular orientation, but the panels should be shingled in the down-slope direction to facilitate drainage.

Only as much GCL as can be covered by the end of the day should be deployed, or such amount that can be covered in a reasonably short time in the event of precipitation. Uncovered overlap edges should be protected overnight with a plastic membrane to prevent bentonite hydration. The edges of exposed sheets should be weighted down with sandbags or equivalent ballast, which does not cause any damage to the GCL, to prevent uplift in the event of strong winds.

Cutting of GCL may be required at some times, e.g. around penetrations. This can be accomplished by using a sharp utility knife. Frequent blade changes are recommended to avoid damage to the geosynthetic components of the GCL during the cutting process. Removed blades should not be discarded on or under installed GCL.

When the liner is cut to fit in small areas, in corners or around structures adjacent panels should be overlapped a minimum 300 mm, adding abundant bentonite in the overlapped areas, if the overlapped area does not cover a fully bentonite impregnated area.

2.3.3 Attachment Details

GCL should be installed around penetrations, pipes, and other structures according to the contract drawings and guidelines. GCL may be secured to the structures by use of a stainless steel batten or clamp, mechanical fasteners, or other appropriate device if necessary for minimizing movement. Additional bentonite or bentonite paste is necessary to maximize the seal.

The Contractor shall provide the manufacturers' recommended typical GCL attachment to vertical and horizontal pipe penetrations and concrete structure.

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2.3.4 Repairs

In the event that an area of GCL becomes damaged, torn or punctured during installation, the affected area should be repaired. On relatively level surfaces, the damaged area should be

END OF SECTION 3: PARTICULAR SPECIFICATIONS FOR GCL

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SECTION 3: HDPE GEONET PARTICULAR SPECIFICATIONS

3.1 INTRODUCTION

The Contractor shall furnish all labor, materials, tools, supervisions, transportations, and installation equipment necessary for installation of the specified GEONET as per the locations shown on the drawings. The Materials shall be installed in accordance to approved QC procedures in accordance to this specification and to the satisfaction of RAH. The materials supplied for this project shall comply with the specifications described in this document. If the material does not meet project specifications it shall be removed from the work area at the expense of the Contractor.

3.1.1 Requirements

- (1) The geosynthetic drainage nets shall be Single-layered, three-dimensional and high compression resistance drainage system consisting of two extruded strands. The intersecting strands form overlaid sets of continuous deep channels, which provide high flow capacity. The drainage net shall be manufactured by extruding two sets of strands to form a three-dimensional polyethylene structure. It shall have uniform channels, open area and thickness to provide planar water flow.
- (2) The contractor must provide a Certificate of Approval from the Manufacturer to confirm that their Manufacturing Factory's production and management system are certified to be operating under a Quality Management System consistent with at least the Quality Standards. The manufacturer shall be certified to DIN EN ISO 9001(2000) or equivalent.
- (3) Minimum roll width 3.8-m
- (4) Materials and installations shall be performed in accordance with this Construction QA/QC Plan, site specifications and the requirements listed below.
- (5) The RAH Representative activities for Geonets shall include material and source approval and observation during installation.

3.1.2 Physical and Mechanical Properties

Table 1: HDPE GEONET Specifications

Properties	Unit	Values	Test Method
Structure	--	2 Strands	--
Polymer Type	--	HDPE	--
Mass Per Unit Weight	g/m ²	450	ASTM D 3 776 EN ISO 9864 (EN 965)

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Properties	Unit	Values	Test Method
Hydraulic Flow Rate @ A load of 20 kPa	l/(m x s)	1.2 x 10 ⁺⁰	ASTM D 4716 EN ISO 12958
Hydraulic Flow Rate @ A load of 200 kPa	l/(m x s)	1 x 10 ⁺⁰	
Hydraulic Flow Rate @ A load of 1000 kPa	l/(m x s)	2 x 10 ⁻¹	
Tensile Strength	kN/m	4.0	ASTM D 1682 EN ISO 10319
Elongation Peak	%	30	
Thickness at 2kPa	mm	4.1	EN ISO 9863-1 (EN 964-1) ASTM D 1777
Thickness at 20 kPa	mm	4.0	
Thickness at 200 kPa	mm	3.8	

3.1.3 References

- (1) The Geonet shall comply in full with the EN ISO and or ASTM testing standard codes

3.1.4 Submittals

- (1) Submit the following to RAH Representative for review and approval, within one week from receiving the Letter of award to expedite shipment or installation of the GEONET:
 - A- Manufacturer's Quality Control program manual and material properties sheet, including at a minimum all properties specified in section 1.01, and 1.02 above.
 - B- Sample of the materials
 - C- Documentation of Installer's qualifications, as specified
 - (i) Submit a list of projects including: name and type of facility; its location; the date of installation; name and telephone number of contact at the facility; type of GEONET and; surface area of the installed GEONET.
 - (ii) Submit the Quality Control Program.
 - (iii) Submit the CV of the Quality Control Engineer
 - D- Submit sample Material Warranty and Installation Warranty
 - E- Submit the execution plan
 - F- Delivery and installation schedule and milestones
 - G- Method statement and job safety analyses for the day to day installation

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(2) Shop Drawings

- A- Submit copies of shop drawings for RAH's approval within two weeks after obtaining the materials and installation approvals. Shop drawings shall show the proposed panel layout identifying seams and details. Seams should generally follow the direction of the slope. Roll-end seams should not occur on a slope unless approved by RAH
- B- Placement of geonet should not be allowed to proceed until RAH has received and approved the shop drawings.

(3) Additional Submittals (In-Progress and at Completion)

- A- Manufacturer's warranty
- B- Geonet installation warranty
- C- Daily written acceptance of subgrade surface
- D- Daily field installation reports
- E- Installation record and as built drawings

3.1.5 Manufacturer & Installer Qualifications

(1) Manufacturer's Qualifications:

The manufacturer of geonet of the type specified shall have at least five years' experience in the manufacture of such geonet. In addition, the geonet manufacturer shall have manufactured at least 1,000,000 M² of the specified type of geonet or similar product during the last five years.

(2) Installer's Qualifications

- A- The Geonet Installer shall be the Manufacturer, approved Manufacturer's Installer or a Contractor approved by RAH Representative to install the Geonet.
- B- The Geonet Installer shall have at least three years' experience in the installation of the specified Geonet. The Geonet Installer shall have installed at least 3 projects involving a total of 100,000 m2 of Geonet in the last three years.
- C- Installation shall be performed under the direction of a field Installation Quality Control Engineer who shall be responsible throughout the Geonet installation, for Geonet panel

Business Use



layout, seaming, patching, testing, repairs, and all other activities of the Geonet including daily documentations and reports.

- D- All seaming, patching shall be performed by qualified technicians employed by the Geonet Installer.

3.1.6 Storage and Handling

- (1) Geonets shall be loaded at the manufacturing facility in such a way that damage during shipment does not occur.
- (2) Upon delivery, geonet rolls should be unloaded and transported with standard construction equipment utilizing a spreader bar and core bar, forklift equipment with a stinger pole, or by means of suitable loading belts. Alternatively, the rolls may be unloaded manually provided that damages during manual unloading are avoided and RAH Representative approves such process. Geonet transportation and handling on site should be done in similar matter.
- (3) Geonet should be stored on a flat surface provided by the Contractor. The flat surface should protect the Geonet from damage, abrasions, excessive dirt and moisture. The surface shall be smooth and leveled and protect from vandalism. If Geonet rolls are stacked on top of each other the maximum height may not exceed 5 rolls. They shall also be secured against movement caused by any means.

3.1.7 Material Warranty

10-years from the shipping date.

3.1.8 Geonet Installation Warranty

- (1) The Geonet Installer shall guarantee the Geonet installation against defects in the installation and workmanship for 1 year commencing from the date of final acceptance.

3.1.9 Pre-Construction Meeting

- (1) Geonet Pre-Construction Meeting shall be held at the site prior to installation of the geonet. At a minimum, the meeting shall be attended by the Contractor, RAH Representative and the Earthwork Contractor.
- (2) Topics for this meeting shall include:
A- Health and Safety

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- B- Lines of authority and communication; Resolution of any project document ambiguity
 - C- Methods for documenting, reporting and distributing documents and reports
 - D- Procedures for packaging and storing archive samples.
 - E- Review of time schedule for all installation and testing.
 - F- Review of panel layout and numbering systems for panels and seams including details for marking on Geonet.
 - G- Procedures and responsibilities for preparation and submission of as-built panel and seam drawings
 - H- Deployment techniques
 - I- Measurement and payment schedules
 - J- Responsibilities of each party
- (3) The meeting shall be documented by a person designated at the beginning of the meeting and minutes shall be transmitted to all parties.

3.2 GEONET PRODUCT

3.2.1 Manufacturers Quality Control

- (1) The Geonet shall be supplied in rolls wrapped in impermeable protective covers and labeled with the following information:
 - A- Manufacturer's name;
 - B- Roll number;
 - C- Product identification; and
 - D- Roll dimensions
- (2) The test methods and frequencies used by the manufacturer for quality control/quality assurance of the specified Geonet prior to delivery shall be in accordance with EN ISO and ASTM standards.
- (3) The manufacturer's Geonet quality control certifications, including results of quality control testing of the products, as specified below, shall be supplied to RAH Representative to verify that the materials supplied for the project are in compliance with all product specifications in this Section. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services

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Manager. Certifications shall include lot and roll numbers and corresponding shipping information.

- (4) The quality control certificates shall include:
- roll identification numbers;
 - sampling procedures; and
 - Results of quality control testing.
- (5) The Geonet Manufacturer shall provide, as a minimum, test results for the following:
- mass per unit area;
 - tensile strength;
 - elongation;
 - thickness; and
 - permeability
- (6) Quality control tests shall be performed in accordance with the test methods specified in Section (2.3.2) for every 10,000 m² of Geonet produced for the project.
- (7) RAH Representative shall examine all Manufacturer certifications to ensure that the property values listed on the certifications meet or exceed those specified for the particular type of Geonet and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency.

3.3 CONFORMANCE AND TESTING

3.3.1 Tests

Upon delivery of the rolls of Geonets, RAH Representative shall ensure that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to ensure conformance to both the design specifications and the list of guaranteed properties. These conformance tests shall be performed in accordance with the test methods specified in the project specifications. This requirement may be waived by RAH if manufacturer quality control procedures are of high quality and satisfies RAH review requirements.

3.3.2 Sampling procedure

Samples shall be taken across the entire width of the roll and should not include the first 1-m. the sample size shall be 1 m long by the roll width. RAH Representative shall mark the machine direction on the samples with an arrow. The samples shall be taken at a rate of one

Business Use



per lot or one per 10,000 m2. The following are the Conformance Testing Requirement form Geonet

- Mass per unit area;
- Thickness
- tensile strength; and
- elongation;

3.3.3 Test Results

RAH Representative shall examine all results from laboratory conformance testing and shall report any non-conformance to the Project Director.

3.3.4 Conformance Test Failure

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

- (1) The Manufacturer shall replace every roll of Geonet that is in non-conformance with the specifications with a roll that meets specifications.
- (2) The Installer shall remove conformance samples for testing by the Geosynthetic CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples shall conform to the specifications. If either of these samples fails, the numerically closest rolls on the side of the failed sample that is not tested shall be tested by the Geosynthetic CQA Laboratory. These samples shall conform to the specifications. If any of these samples fail, every roll of Geonet on site from this lot and every subsequently delivered roll that is from the same lot shall be tested by the Geosynthetic CQA Laboratory for conformance to the specifications. This additional conformance testing shall be at the expense of the Manufacturer.
- (3) RAH Representative shall document actions taken in conjunction with conformance test failures.

3.4 EXECUTION

3.4.1 Geonet Installation

- (1) Prior to installation of Geonet the subgrade or the underlying material (e.g. geosynthetic) shall be approved by RAH Representative. The Geonet placement methods and equipment should be evaluated appropriately. Geonet rolls should always be installed in the direction of flow unless otherwise specified.

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- (2) The installer shall take any necessary precautions during the placement of Geonet rolls to prevent any damage to the underlying subgrade or layer. In no case is it permitted that construction traffic may drive directly over the Geonet. Full-length rolls should be used on the total slope length.
- (3) The geonet shall be properly anchored to resist sliding. Compactors or other compacting equipment shall not be permitted to come in direct contact with the Geonet to prevent damage of the geonet during compaction of the anchor trench fill.
- (4) Sandbags should be placed on installed Geonet to avoid wind lift or an equivalent measure should be taken in the case of wind presence. The sandbags shall be removed prior to the placement of the next layer.

3.4.2 Overlaps Seaming

Adjacent Geonet rolls shall be installed in such a way that a constant flow between the rolls is ensured.

Adjacent roll length edges of the Geonet shall be placed in such a way that the edges are butted against each other. Each Geonet can be fixed to the adjacent roll at overlaps to avoid adjacent rolls from separating during cover soil or material placement. The butted edges can be secured against each other by using cable ties, so that they have a direct contact. The distance between the cable tie fixing should be 0.75 m.

Adjacent ends of Geonet rolls are recommended to be carried out with 15 cm wide overlaps by shingling them like roof tiles in the direction of the slope (flow direction). Cable ties in a distance of 30 cm can be used to secure the geonet from separating during cover soil placement.

3.4.3 Penetrations and Connections

If Geonet rolls are installed against structures or if structures penetrate the Geonet a constant flow shall be ensured. This can be done by placing the Geonet directly against the structure or by using an extra layer of Geonet and overlapping a patch in the area of the connection or penetration. In some cases an apron may be suitable. The overlapping Geonet can be fixed to the adjacent roll to avoid Geonet separation during cover soil or material placement

3.4.4 Cover geotextile Placement

The placement of the approved cover geotextile shall be carried without equipment driving directly on the Geonet. The placement the cover geotextile shall not damage Geonet.

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3.4.5 Repair of Damaged Geonet

Prior to placement of the specified cover geotextile on top of the installed Geonet, each installed roll shall be inspected for damage resulting from installation activities. Any damaged areas (i.e. rips, tears, etc.) on the installed Geonet shall be repaired. This can be done by patching or replacing the damaged area. The patching shall overlap the damaged area by minimum 30 cm and be fixed to the undamaged area by using cable ties every 15 cm. If the width of the damaged area to be repaired is larger than 2 m, the damaged area shall be cut out in the whole width and a new roll shall be attached as described in the previous described sections.

3.4.6 Geonet Liner Acceptance

- (1) Geonet liner shall be accepted by RAH Representative when:
 - A- The agreed upon subsection of the installation is finished;
 - B- All Installer's QC documentation is completed and submitted to RAH
 - C- Verification of the adequacy of all field seams and repairs and associated Geonet testing is complete.

3.4.7 Anchorage

- (1) As directed by the project drawings and specifications, the end of the Geonet roll shall be placed in an anchor trench at the top of the slope. Loose soil should be removed from the floor of the trench (top of geotextile laid in the trench).

3.5 SAFETY PRECAUTIONS

- (1) Personnel working on the Geonet shall not smoke or wear damaging shoes.
- (2) The surface of the Geonet shall not be used as a working area for sorting tools and supplies. If needed, a protective cover shall be spread out as a working surface.

END OF SECTION 4: HDPE GEONET PARTICULAR SPECIFICATIONS

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SECTION 4: GEOGRID GEOCOMPOSITE PARTICULAR SPECIFICATIONS

4.1 INTRODUCTION

The Contractor shall furnish all labor, materials, tools, supervisions, transportations, and installation equipment necessary for installation of the specified Geogrid as per the locations shown on the construction drawings. The Materials shall be installed in accordance to approved QC procedures and to the satisfaction of RAH. The materials supplied for this project shall comply with the specifications described in this document. If the material does not meet project specifications it shall be removed from the work area at the expense of the Contractor

4.1.1 Requirements

The geo-composite Geogrid shall be made of stretched, monolithic polypropylene (PP) flat bars with welded junctions and a mechanical bonded filter geotextile welded within the Geogrid structure and meeting the physical and mechanical properties listed in Table-1 below

- (1) The contractor must provide a Certificate of Approval from the Manufacturer to confirm that their Manufacturing Factory's production and management system are certified to be operating under a Quality Management System consistent with at least the Quality Standards The manufacturer shall be certified to DIN EN ISO 9001(2000) or equivalent.
- (2) Minimum roll width 4.75-m
- (3) Materials and installations shall be performed in accordance with an approved QC plan and in line with the Construction QA/QC Plan described herein.
- (4) The Geosynthetic CQA Consultant activities for Geogrid shall include material and source approval and observation during installation.

4.1.2 Physical and Mechanical Properties

Table 1: Geogrid Geocomposite Specifications

Properties	Test Method	Unit	Values
Geogrid Raw material			polypropylene
Mass per unit area	EN ISO 9864	g/m ²	200
Max. tensile strength, md / cmd**	EN ISO 10319	kN/m	≥ 30 / ≥ 30
Elongation at nominal strength ,md / cmd**	EN ISO 10319	%	≤ 8 / ≤ 8
Tensile strength at 2% elongation, md / cmd**	EN ISO 10319	kN/m	12 / 12

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Tensile strength at 5% elongation, md / cmd**	EN ISO 10319	kN/m	12 / 12
Aperture size, md x cmd**		mm x mm	32 x 32
Production specific elongation		%	0
Geotextile			
Raw material			polypropylene
Mass per unit area	EN ISO 9864	g/m ²	150
Max. tensile strength, md / cmd**	EN ISO 10319	kN/m	6.0 / 10.0
Elongation at max. tensile strength, md / cmd**	EN ISO 10319	%	50 / 30
Puncture force	EN ISO 12236	N	1,670
Displacement at static puncture strength	EN ISO 12236	mm	30
Detector tested		-	yes
**md = machine direction, cmd = cross machine direction			

4.1.3 References

- (1) The Geogrid shall comply in full with the EN ISO and or ASTM testing standard codes

4.1.4 Submittals

- (1) Submit the following to the Engineer for review and approval, within one week from receiving the Letter of award to expedite shipment and installation of the GEOGRID:
 - A- Manufacturer's Quality Control program manual and material properties sheet, including at a minimum all properties specified in section 1.01, and 1.02 above.
 - B- Sample of the materials
 - C- Documentation of Installer's qualifications, as specified
 - (i) Submit a list of projects including: name and type of facility; its location; the date of installation; name and telephone number of contact at the facility; type of GEOGRID and; surface area of the installed GEOGRID.
 - (ii) Submit the Quality Control Program.
 - (iii) Submit the CV of the Quality Control Engineer
 - D- Submit sample Material Warranty and Installation Warranty
 - E- Submit the execution plan
 - F- Delivery and installation schedule and milestones

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G- Method statement and job safety analyses for the day to day installation

(2) Shop Drawings

- A- Submit copies of shop drawings for engineer's approval within two weeks after obtaining the materials approvals. Shop drawings shall show the proposed panel layout identifying seams and details. Seams should generally follow the direction of the slope. Roll-end seams should not occur on a slope unless approved by RAH
- B- Placement of Geogrid should not be allowed to proceed until RAH has received and approved the shop drawings.

(3) Additional Submittals (In-Progress and at Completion)

- A- Manufacturer's warranty
- B- Geogrid installation warranty
- C- Daily written acceptance of subgrade surface
- D- Daily field installation reports
- E- Installation record and as built drawings

4.1.5 Manufacturer & Installer Qualifications

(1) Manufacturer's Qualifications:

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

(2) Installer's Qualifications

- A- The Geogrid Installer shall be the Manufacturer, approved Manufacturer's Installer or a contractor approved by RAH Representative to install the Geogrid.
- B- The Geogrid Installer shall have at least three years' experience in the installation of the specified Geogrid. The Geogrid Installer shall have installed at least 3 projects involving a total of 100,000 m² of Geogrid in the last three years.
- C- Installation shall be performed under the direction of a field Installation Quality Control Engineer who shall be responsible throughout the Geogrid installation, for Geogrid

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panel layout, seaming, patching, testing, repairs, and all other activities of the Geogrid including daily documentations and reports.

- D- All seaming, patching shall be performed by qualified technicians employed by the Geogrid Installer.

4.1.6 Storage and Handling

- (1) Geogrids shall be loaded at the manufacturing facility in such a way that damage during shipment does not occur.
- (2) Geogrids received shall be verified by RAH as being the type, grade required for the project, as defined herein. Material shall be clearly marked, and in good condition before acceptance by RAH
- (3) Geogrids are transported and stored in rolls, and may be stacked on top of each other, but no more than seven rolls in height. If stored on the ground, tarpaulin shall be laid at first to protect rolls from collecting dirt from site. A tarpaulin for protection from the elements shall cover material stored onsite for a period exceeding two months.
- (4) Upon delivery, Geogrid rolls should be unloaded and transported with standard construction equipment utilizing a spreader bar and core bar, forklift equipment with a stinger pole, or by means of suitable loading belts. Alternatively, the rolls may be unloaded manually provided that damages during manual unloading are avoided and the geosynthetic consultant approves such process.
- (5) Geogrids may be installed either manually or by use of mechanized equipment. Edges of the Geogrid rolls can be sharp, so gloves may be used during hand carrying and placement to prevent injury. Mechanized equipment may be used providing the said installation equipment does not damage the Geogrid during this process. Handling procedures shall be submitted and approved by RAH

4.1.7 Manufacturer Material Warranty

10-years from the shipping date.

4.1.8 Geogrid Installation Warranty

- (1) The Geogrid Installer shall guarantee the Geogrid installation against defects in the installation and workmanship for 1 year commencing from the date of final acceptance.

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4.1.9 Pre-Construction Meeting

- (1) A Geogrid Pre-Construction Meeting shall be held at the site prior to installation of the Geogrid. At a minimum, the meeting shall be attended by the Contractor and RAH Representative and other evolved parties.

4.1.10 Topics for this meeting shall include:

- (1) Health and Safety
- (2) Lines of authority and communication; Resolution of any project document ambiguity
- (3) Methods for documenting, reporting and distributing documents and reports
- (4) Procedures for packaging and storing archive samples.
- (5) Review of time schedule for all installation and testing.
- (6) Review of panel layout and numbering systems for panels and seams including details for marking on Geogrid.
- (7) Procedures and responsibilities for preparation and submission of as-built panel and seam drawings
- (8) Deployment techniques
- (9) Measurement and payment schedules
- (10) Responsibilities of each party

The meeting shall be documented by a person designated at the beginning of the meeting and minutes shall be transmitted to all parties.

4.2 GEOGRID PRODUCT

4.2.1 Manufacturers Quality Control

- (1) The Geogrid shall be supplied in rolls wrapped in impermeable protective covers and labelled with the following information:
 - A- Manufacturer's name;
 - B- Roll number;
 - C- Product identification; and
 - D- Roll dimensions

Business Use



- (2) The test methods and frequencies used by the manufacturer for quality control/quality assurance of the specified Geogrid prior to delivery shall be in accordance with EN ISO and ASTM standards.
- (3) The manufacturer's Geogrid quality control certifications, including results of quality control testing of the products, as specified below, shall be supplied to the RAH Representative to verify that the materials supplied for the project are in compliance with all product specifications in this Section. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.
- (4) The quality control certificates shall include:
 - Roll identification numbers;
 - Sampling procedures; and
 - Results of quality control testing.
- (5) The Geogrid Manufacturer shall provide, as a minimum, test results for the following:
 - mass per unit area;
 - Mass per unit area
 - Max. tensile strength, md / cmd
 - Elongation at nominal strength ,md / cmd
 - Tensile strength at 2% elongation, md / cmd
 - Tensile strength at 5% elongation, md / cmd
 - Aperture size, md x cmd
- (6) Quality control tests shall be performed in accordance with the test methods specified in Table-1 above for every 10,000 m² of Geogrid produced for the project.
- (7) RAH Representative shall examine all Manufacturer certifications to ensure that the property values listed on the certifications meet or exceed those specified for the particular type of Geogrid and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency.

4.3 CONFORMANCE AND TESTING

4.3.1 Tests

Upon delivery of the rolls of Geogrids, RAH Representative shall ensure that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to ensure conformance to both the design specifications and the list of guaranteed properties. These conformance tests shall be performed in accordance with the test methods specified in the

Business Use



project specifications. This requirement may be waived by RAH if manufacturer quality control procedures are of high quality and satisfies RAH review requirements.

4.3.2 Sampling procedure

Samples shall be taken across the entire width of the roll and should not include the first 1-m. the sample size shall be 1 m long by the roll width. RAH Representative shall mark the machine direction on the samples with an arrow. The samples shall be taken at a rate of one per lot or one per 10,000 m². The following are the Conformance Testing Requirement form Geogrid

- Mass per unit area
- Max. tensile strength, md / cmd
- Elongation at nominal strength ,md / cmd
- Tensile strength at 2% elongation, md / cmd
- Tensile strength at 5% elongation, md / cmd
- Aperture size, md x cmd

4.3.3 Test Results

RAH representative will examine all results from laboratory conformance testing and shall report any non-conformance to RAH landfill projects manager.

4.3.4 Conformance Test Failure

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

- (1) The Manufacturer shall replace every roll of Geogrid that is in non-conformance with the specifications with a roll that meets specifications.
- (2) The Installer shall remove conformance samples for testing by the Geosynthetic CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples shall conform to the specifications. If either of these samples fails, the numerically closest rolls on the side of the failed sample that is not tested shall be tested by the Geosynthetic CQA Laboratory. These samples shall conform to the specifications. If any of these samples fail, every roll of Geogrid on site from this lot and every subsequently delivered roll that is from the same lot shall be tested by the Geosynthetic CQA Laboratory for conformance to the specifications. This additional conformance testing shall be at the expense of the Manufacturer.
- (3) RAH Representative shall document actions taken in conjunction with conformance test failures.

Business Use



4.4 EXECUTION

4.4.1 Geogrid Installation

- (1) Prior to installation of Geogrid the subgrade or the underlying material (e.g. geosynthetic) shall be approved by the geosynthetic consultant and the installer's QC engineer. The Geogrid placement methods and equipment should be evaluated appropriately.
- (2) The installer shall take any necessary precautions during the placement of Geogrid rolls to prevent any damage to the underlying liner. In no case is it permitted that construction traffic may drive directly over the Geogrid.
- (3) The Geogrid shall be properly anchored to resist sliding. Equipment shall not be permitted to come in direct contact with the Geogrid to prevent damage of the Geogrid and underlying liner.
- (4) Sandbags should be placed on installed Geogrid to avoid wind lift or an equivalent measure should be taken in the case of wind presence. The sandbags shall be removed prior to the placement of the concrete or soil layer.
- (5) All wrinkles and folds shall be removed. When required, Geogrid may be pre-tensioned to eliminate slack.

4.4.2 Overlaps and Seaming

Adjacent roll length edges of the Geogrid shall be placed in such a way that the edges are butted against each other. Each Geogrid can be fixed to the adjacent roll at overlaps to avoid adjacent rolls from separating during concrete placement. The butted edges can be secured against each other by using cable ties, so that they have a direct contact. The distance between the cable tie fixing should be 0.75 m.

Geogrid shall be overlapped a minimum of 300 mm in both adjacent and longitudinal directions.

4.4.3 Concrete Placement

Prior to concrete placement the Geogrid shall be inspected by the Geosynthetic Consultant to make sure it is placed in the proper location, and has not been damaged during this installation. Damaged Geogrid, as determined by the engineer shall be repaired immediately, either by replacement or by patching to suitably cover the damaged area.

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Concrete shall be placed from the bottom to the top of the slope upward. If this is not possible, the contractor shall propose other methods for the approval of RAH. In any case the procedure may not cause any damage to the Geogrid.

The liner installer shall provide concrete placement method statement based on manufacturer recommended procedures for the placement of concrete.

4.4.4 Repair of damaged Geogrid.

Prior to any covering process of the installed Geogrid, each installed roll shall be inspected for damage resulting from construction. Any damaged areas (i.e. rips, tears, etc) on the installed Geogrid shall be repaired. This can be done by patching or replacing the damaged area. The patching shall overlap the damaged area by minimum 50 cm and be fixed to the undamaged area by using cable ties every 15 cm. If the width of the damaged area to be repaired is larger than 2 m, the damaged area shall be cut out in the whole width and a new roll shall be attached.

4.4.5 Liner Acceptance

- (1) Geogrid Geocomposite shall be accepted by RAH Representative when:
 - A- The agreed upon subsection of the installation is finished;
 - B- All Installer's QC documentation is completed and submitted to RAH
 - C- Verification of the adequacy of all field seams and repairs and associated Geogrid testing is complete.

4.4.6 Anchorage

- (1) As directed by the project drawings and specifications, the end of the GEOGRID roll shall be placed in an anchor trench at the top of the slope. Loose soil should be removed from the floor of the trench (top of geotextile laid in the trench).

4.5 SAFETY PRECAUTIONS

- (1) Personnel working on the GEOGRID shall not smoke or wear damaging shoes.
- (2) The surface of the GEOGRID shall not be used as a working area for sorting tools and supplies. If needed, a protective cover shall be spread out as a working surface.

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END OF SECTION 5 GEOGRID GEOCOMPOSITE PARTICULAR SPECIFICATIONS

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SECTION 5: GEOTEXTILE PARTICULAR SPECIFICATIONS

5.1 INTRODUCTION

The Contractor shall furnish all labor, materials, tools, supervisions, transportations, and installation equipment necessary for installation of the specified Geotextiles as per the locations shown on the construction drawings. The Materials shall be installed in accordance to approved QC procedures and to the satisfaction of RAH The materials supplied for this project shall comply with the specifications described in this document.

5.1.1 Requirements

- (1) The construction of the landfill, soil-geosynthetic-lining-system requires the utilization of two types of geotextiles each having its unique physical properties to perform as designed
- (2) Table-1 below provides the specifications and the physical properties of geotextile to be laid directly on top of cross fall, internal & external slopes of the landfill and evaporation ponds for the propose of separation and liner protection. This geotextile will be referred to as type 1 geotextile. The primary function of type-1 geotextile is to provide protection for the GCL materials against salts present in the soil and puncture from the underlying soil. Type-1 Geotextile shall have puncture CBR in the range of 3.5 KN.
- (3) Table-2 below provides the specifications and physical properties for the geotextile to be laid on top of the geonet for the protection of the lining system and as a filter. This geotextile will be referred to as type- 2 geotextile. Type-2 geotextile is selected to allow for long-term passage of water into the geonet while retaining the in-situ soil and protecting the HDPE liner form potential damage from the top drainage layer. The geosynthetics consultant shall confirm the applicability of the tensile strength of the geotextile to meet the minimum required strength based on stability analyses and shear box test results. The geotextile must, at minimum meet the required tensile strength. If higher grade geotextile is required due to increase in slope length, the contractor shall pay the difference in price and shall consider this in his price. The geosynthetics consultant shall evaluate the protection behaviour of the geotextile laid on the top of the geonet to ensure the lining system is subject to best protection, if higher better protection is required due to the shape of soil and loading condition, then the geosynthetics consultant shall provide his analyse and recommendation to the contractor and the contractor shall submit to RAH for RAH for consideration and the contractor shall pay the difference in price and shall consider this in his price.
- (4) The primary function type-2 geotextile are as follows:

Business Use



Protection: Geotextile protection properties are function of geotextile puncture resistance (CBR). Type-2 geotextile shall have puncture CBR in the range of 10.5 KN.

Filtration: Geotextile filtration properties are a function of the in-situ soil gradation, plasticity, geotextile opening size and hydraulic conditions; this shall further be verified prior to installation of materials. Based on soil gradation, the required geotextile shall have an opening size (O_{90}) in the range of 0.22- mm to 0.60mm and shall have 80% to 100% UV protection The Contractor shall furnish all labor, materials, tools, supervisions, transportations, and installation equipment necessary for installation of the Geotextile layers, as shown on the Drawings, and in accordance with the standards (i.e. DIN, ASTM AASHTO).

- (5) The Contractor shall coordinate the installation of the Geotextiles with other construction activities and contractors at the site.
- (6) If the material does not meet project specifications it will be removed from the work area at the expense of the contractor.
- (7) The Contractor shall submit an installation method statement including panel layout and seaming procedures for approval prior to commencement of installation.
- (8) Geotextile materials shall be confirmed with specifications listed below.

5.1.2 Geotextile Specifications

- (1) The geotextile shall be manufactured from raw Polypropylene materials inert to environmental influences.
- (2) The Geotextile shall be non-biodegradable, and have excellent resistance to chemicals and salts normally present in the soil.
- (3) The geotextile shall be manufactured by accredited manufacturer applying Laboratory Accreditation Program (GAI-LAP).
- (4) The Geotextile manufacturer shall furnish materials with “Minimum Average Roll Values”. The Geotextile components shall meet or exceed the criteria listed in Table-1 and Table- 2.
 - A- Minimum Average Roll Value (MARV): Property value calculated as typical minus two standard deviations. Statistically, it yields a 97.7 percent degree of confidence that any sample taken during quality assurance testing will exceed value reported.
 - B- Maximum Average Roll Value (Max ARV): Property value calculated as typical plus two standard deviations. Statistically, it yields a 97.7 percent degree of confidence that any sample taken during quality assurance testing will be below the value reported.

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- C- Typical Roll Value: Property value calculated from average or mean obtained from test data.

Table 1: Geotextile specification (TYPE 1)

Property	Test Method	Units	Property Requirement	
			MD	X-MD
Tensile Strength	EN ISO 10 319	KN/M	30-35	30-35
Tensile Force at 5% strain	EN ISO 10 319	KN/M	15-20	15-20
Strain at maximum load	EN ISO 10 319	%	10-12	8-10
Puncture CBR	EN ISO 12 236	KN	3.3- 4.0	
Opening Size O ₉₀	EN ISO 12 956	um	. 0.22-mm-.43mm	
UV Resistance	EN ISO 12 224	%	70%- 100%	

Table 2: (TYPE 2) Geotextile specification

Property	Test Method	Units	Property Requirement	
			MD	X-MD
Tensile Strength	EN ISO 10 319	KN/M	52-70	52-70
Tensile Force at 5% strain	EN ISO 10 319	KN/M	15-20	30-40
Strain at maximum load	EN ISO 10 319	%	20-25	8-10
Puncture CBR	EN ISO 12 236	KN	7.1 -14	
Opening Size O₉₀	EN ISO 12 956	um	Min. 0.17mm; Max. 0.22mm_.6mm	
Water Permeability	EN ISO 11 058	mm/s	15-20	
UV Resistance	EN ISO 12 224	%	80%100%	

Business Use



5.1.3 References

- (1) The Geotextile shall comply in full with DIN or the American Society for Testing and Materials (ASTM) and/or AASHTO standards.

5.1.4 Submittals

- (1) Submit the following for review and approval, within one week from receiving the Letter of award to expedite shipment and installation of the Geotextiles:
 - A- Manufacturer's Quality Control program manual and material properties sheet, including at a minimum all properties specified in Table-1 and Table-2 Above.
 - B- Sample of the materials
 - C- Certification:
 - (i) The Contractor shall provide a certificate stating the name of the geotextile manufacturer, product name, style, chemical compositions of filaments or yarns and other pertinent information to fully describe the geotextile.
 - (ii) The Manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.
 - (iii) The manufacturer's certificate shall state that the furnished geotextile meets MARV requirements of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the Manufacturer shall attest to the certificate.
 - D- Documentation of Installer's qualifications, as specified
 - (i) Submit a list of projects including: name and type of facility; its location; the date of installation; name and telephone number of contact at the facility; type of Geotextile and; installed surface area.
 - (ii) Submit Construction Quality Control Plan (CQC) in accordance to USEPA requirements as described in USEPA technical Guidance document "Quality control for waste Containment Facilities" EPA/600/R-93/182

Business Use



(iii) Submit the CV of the Quality Control Engineer

- E- Submit sample Material Warranty and Liner Installation Warranty
- F- Submit the execution plan
- G- Submit manpower histogram
- H- Delivery and installation schedule and milestones
- I- Method statement and job safety analyses for the day-day installation
- J- Contingency plan for material delivery and equipment breakdown
- K- Delivery and installation schedule and milestones

(2) Shop Drawings

- A- Submit copies of shop drawings for approval within two weeks after obtaining the materials approval. Shop drawings shall show the proposed panel layout identifying seams and details. Seams should generally follow the direction of the slope. Butt seams or roll-end seams should not occur on a slope unless approved by the Geosynthetics Consultant.
- B- Placement of geotextiles should not be allowed to proceed until the Consultant and RAH have received and approved the shop drawings.

(3) Additional Submittals (In-Progress and at Completion)

- A- Manufacturer's warranty
- B- Installation warranty
- C- Daily written acceptance of subgrade surface
- D- Prequalification test seam samples
- E- Daily field installation reports
- F- Installation record drawing

Business Use



5.1.5 Manufacturer & Installer Qualifications

(1) Manufacturer's Qualifications:

The manufacturer of Geotextile of the type specified shall have at least 15 years' experience in the manufacture of such Geotextile. In addition, the Geotextile manufacturer shall have manufactured at least 10,000,000 m² of the specified type of Geotextile or similar product during the last five years.

(2) Installer's Qualifications

- A- The Geotextile Installer shall be the Manufacturer, approved Manufacturer's Installer. The Geotextiles Installer shall have at least five years' experience in the installation of the specified Geotextiles. The Geotextiles Installer shall have installed at least 3 projects involving a total of 500,000 m² of Geotextiles in the last three years.
- B- Installation shall be performed under the direction of a field Installation Quality Control Engineer who shall be responsible throughout the Geotextiles installation, for Geotextiles panel layout, seaming, patching, testing, repairs, and all other activities of the Geotextiles including daily documentations and reports.
- C- All seaming, patching shall be performed by qualified technicians employed by the contractor.

5.1.6 Storage and Handling

- (1) Geotextile labeling, shipment and storage shall follow applicable standards.
- (2) Product labels shall clearly show the manufacturer or supplier name, style name, and roll number.
- (3) Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.
- (4) Each geotextile roll shall be wrapped with a material that will protect the geotextile from damage due to shipment, water, sunlight, and contaminants.
- (5) The protective wrapping shall be maintained during periods of shipment and storage. If the wrapping is damaged prior to installation, the outer wrap of geotextile material shall be discarded before installation.
- (6) During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: Site construction damage, extended exposure to ultraviolet (UV) radiation, precipitation, chemicals that are strong acids or strong bases, flames, sparks,

Business Use



temperatures in excess of 71 degree C (160 degree F) and any other environmental condition that might damage the geotextile.

5.1.7 Material Warranty

10-years from the shipping date.

5.1.8 Installation Warranty

- (1) The Geotextiles Installer shall guarantee the Geotextiles installation against defects in the installation and workmanship for 1 year commencing from the date of final acceptance.

5.1.9 Pre-Construction Meeting

- (1) Geotextiles Pre-Construction Meeting shall be held at the site prior to installation of the Geotextile. At a minimum, the meeting shall be attended by the contractor, RAH Representative and the Earthwork Contractor.
- (2) Topics for this meeting shall include:
 - A- Health and Safety
 - B- Lines of authority and communication; Resolution of any project document ambiguity
 - C- Methods for documenting, reporting and distributing documents and reports
 - D- Procedures for packaging and storing archive samples.
 - E- Review of time schedule for all installation and testing.
 - F- Review of panel layout and numbering systems for panels and seams including details for marking on Geotextiles.
 - G- Procedures and responsibilities for preparation and submission of as-built panel and seam drawings
 - H- Deployment and seaming techniques
 - I- Measurement and payment schedules
 - J- Responsibilities of each party

Business Use



- (3) The meeting shall be documented by a person designated at the beginning of the meeting and minutes shall be transmitted to all parties.

5.2 GEOTEXTILE PRODUCT

5.2.1 Manufacturers Quality Control

- (1) Manufacturing Quality Control (MQC): Testing shall be performed at a laboratory accredited by GAI-LAP for tests required for the geotextile, at frequency exceeding ASTM D 4354.
- (2) The Contractor shall submit durability test results for environmental impact resistance; UV stability; oxidative degradations; chemical resistance; microbiological Durability; creep behaviour; and temperature stability
- (3) Product labels shall clearly show the manufacturer or supplier name, style name, and roll number.
- (4) Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.
- (5) Each geotextile roll shall be wrapped with a material that will protect the geotextile from damage due to shipment, water, sunlight, and contaminants and labelled with the following information:
 - A- Manufacturer's name;
 - B- Roll number;
 - C- Product identification; and
 - D- Roll dimensions
- (6) The protective wrapping shall be maintained during periods of shipment and storage.
- (7) The manufacturer's Geotextiles quality control certifications, including results of quality control testing of the products, shall be supplied to RAH Representative to verify that the materials supplied for the project are in compliance with all product specifications in this Section. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.
- (8) The quality control certificates shall include:
 - Roll identification numbers;
 - Sampling procedures; and

Business Use



- Results of quality control testing.

- (9) RAH will examine all Manufacturer certifications to ensure that the property values listed on the certifications meet or exceed those specified for the particular type of Geotextile and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency.

5.3 CONFORMANCE AND TESTING

5.3.1 Tests

Upon delivery of the rolls of Geotextile, RAH Representative will ensure that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to ensure conformance to both the design specifications and the list of guaranteed properties. These conformance tests will be performed in accordance with the test methods specified in the project specifications. This requirement may be waived by RAH if manufacturer quality control procedures are of high quality and satisfies RAH review requirements.

5.3.2 Sampling procedures

Samples will be taken across the entire width of the roll and will not include the first three feet (linear meter). Unless otherwise specified, samples will be 1 m long by the roll width. RAH Representative will mark the machine direction on the samples with an arrow. Unless otherwise specified, samples will be taken at a rate of one per lot or one per 10,000 m², whichever is least, as indicated in Table (3).

Table 3 Geotextile Conformance Testing Requirement

Property	Test Method	Minimum Frequencies
Tensile Strength	EN ISO 10 319	1 Test per 10,000 m ²
Tensile Force at 5% strain	EN ISO 10 319	1 Test per 10,000 m ²
Strain at maximum load	EN ISO 10 319	1 Test per 10,000 m ²
Puncture CBR	EN ISO 12 236	1 Test per 10,000 m ²
Opening Size O ₉₀	EN ISO 12 956	1 Test per 10,000 m ²

Business Use



5.3.3 Test Results

RAH representative will examine all results from laboratory conformance testing and will report any non-conformance to the Project Manager.

5.3.4 Conformance Test Failure

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

- (1) The Manufacturer will replace every roll of Geotextile that is in non-conformance with the specifications with a roll that meets specifications.
- (2) The Installer will remove conformance samples for testing by the Geosynthetic CQA Laboratory from (he closest numerical rolls on both sides of the failed roll. These two samples shall conform to the specifications. If either of these samples fails, the numerically closest rolls on the side of the failed sample that is not tested will be tested by the Geosynthetic CQA Laboratory. These samples shall conform to the specifications. If any of these samples fail, every roll of Geotextile on site from this lot and every subsequently delivered roll that is from the same lot shall be tested by the Geosynthetic CQA Laboratory for conformance to the specifications. This additional conformance testing will be at the expense of the Manufacturer.

The Geosynthetics COA Consultant will document actions taken in conjunction with conformance test failures.

5.4 EXECUTION

5.4.1 Preparation

- (1) Prepare surfaces to receive geotextile to smooth condition as indicated or as directed by QC Engineer.
- (2) Fill depressions and holes flush with adjacent surfaces.
- (3) Remove large stones, limbs, and other debris prior to placement of geosynthetic.

5.4.2 Installation

- (1) The geotextile shall be placed in intimate contact with the soils or liners without wrinkles or folds and anchored on a smooth graded surface approved by RAH. The geotextiles shall be placed in such a manner that placement of the overlying materials will not excessively stretch so as to tear the geotextile. Anchoring of the terminal ends of the geotextile shall be accomplished through the use of key trenches at the crest of slope.

Business Use



- (2) The geotextile shall be placed with the machine direction parallel to the direction of water flow which is normally parallel to the slope. Either sewing or overlapping shall join adjacent geotextile sheets. Overlapped seams of roll ends shall be 300 mm (12 in). Overlap less than 300-mm shall be approved by RAH and or the Consultant and the manufacturer.
- (3) When overlapping, successive sheets of the geotextile shall be overlapped upslope over down slope
- (4) Care shall be taken during installation so as to avoid damage occurring to the geotextile as a result of the installation process. Should the geotextile be damaged during installation, a geotextile patch shall be placed over the damaged area extending 1 m beyond the perimeter of the damage.
- (5) When placing the erosion control (Riprap) materials along the face of the external slopes, the placement shall begin at the toe and proceed up the slope. Placement shall take place so as to avoid stretching and subsequent tearing of the geotextile. Riprap and heavy stone filling shall not be dropped from a height of more than 300 mm. Stone with a mass of more than 100 kg shall not be allowed to roll down the slope.
- (6) Slope protection and smaller sizes of stone filling shall not be dropped from a height exceeding 1 m , or a demonstration provided showing that the placement procedures will not damage the geotextile. All void spaces in the Riprap shall be backfilled with small stone to ensure full coverage.
- (7) Following the placement of the Riprap grading of the slope shall not be permitted if the grading results in movement of the stone directly above the geotextile.
- (8) Field monitoring by RAH will be performed to verify that the Riprap system placement does not damage the geotextile.
- (9) Any geotextile damaged during backfill placement shall be replaced as directed by RAH Representative and contractor QC Engineer, at the Contractor's expense.

5.4.3 Sewn Seams:

- (1) For seams that are to be sewn in the field, the Contractor shall provide at least a 2 meter (6 feet) length of sewn seam for sampling by RAH before the geotextile is installed.
- (2) For seams sewn in both directions, samples of seams from both directions shall be provided to RAH
- (3) For seams that are field sewn, the seams sewn for sampling shall be sewn using the same equipment and procedures as will be used for the production seams.

Business Use



- (4) The Contractor shall submit the seam assembly description. The description shall include the seam type, sewing thread, and stitch density.
- (5) The Sewn may be waived by the Engineer provided that the contractor submits an acceptable alternative approved by RAH
- (6) Sand bags shall be used as necessary to temporarily hold the geotextiles material in position under the foreseeable and reasonably - expected wind conditions.

5.4.4 Protection

- (1) For high performance, Geotextiles should not be exposed to the atmosphere following lay down to more than 30 days to prevent decrease in the mechanical properties of the geotextile. Type-2 geotextile shall have 100% UV resistance at which it would withstand the UV exposure.

5.4.5 Repair of damaged

Prior to any covering process of the installed Geotextile, each installed roll shall be inspected for damage resulting from construction. Any damaged areas (i.e. Tears, etc.) on the installed Geotextile shall be repaired. This can be done by patching or replacing the damaged area. The patching shall overlap the damaged area by minimum 50 cm and be fixed to the undamaged area.

5.4.6 Liner Acceptance

- (1) Geotextile will be accepted by RAH when:
 - A- The agreed upon subsection of the installation is finished;
 - B- All Installer's QC documentation is completed and submitted to the geosynthetics consultant
 - C- Verification of the adequacy of all field seams and repairs and associated geotextile testing is complete.

5.4.7 Anchorage

- (1) As directed by the project drawings and specifications, the end of the geotextile roll shall be placed in the anchor trench at the top of the slope. Loose soil should be removed from the floor of the trench.

Business Use



5.5 SAFETY PRECAUTIONS

- (1) Personnel working on the Geotextile shall not smoke or wear damaging shoes.
- (2) The surface of the Geotextiles shall not be used as a working area for sorting tools and supplies.

END OF SECTION 6 GEOTEXTILES PARTICULAR SPECIFICATION

Business Use



