SECTION 02071
GEOMEMBRANE (HDPE) (MANUFACTURER)

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Supply Geosynthetic Materials Contractor (Contractor) and the Manufacturer referred to throughout this specification may or may not be the same entity.

1. If the Supply Geosynthetic Materials Contractor (Contractor) and the Manufacturer are the same entity, the manufacturer will be responsible for all requirements in this Specification that are the responsibility of the Contractor.

B. The Contractor shall furnish a primary 60-mil, textured, high-density polyethylene (HDPE) geomembrane as a component of the geomembrane liner system as specified in this Section. This includes all labor and resources to collect samples, perform testing, and collect data necessary to furnish all required documentation.

1.02 SUBMITTALS

The Contractor shall submit shop drawings in accordance with Section 01330, Submittals and Acceptance:

A. Manufacturer's Information: Submit the following within 10 days of the Notice to Proceed:

1. The Manufacturer's name, address, and primary contact.

2. The Manufacturing plant name and address where the geomembrane for this project will be produced.

3. The Manufacturer's qualifications including:

a. A minimum of 5 years of successful development and production of geomembrane.
b. Evidence of production of at least 10 million square feet of geomembrane that meets the specifications of Article 2.02.
c. Certification that the Manufacturer has sufficient capacity to provide the required material in the given timeframe.

d. A list of at least 10 projects for which geomembrane has been supplied by the Manufacturer, three of which shall have been for projects of similar size.

4. Product name and the Manufacturer's description of the proposed geomembrane and five representative samples of the product (small samples approximately 5 inches long by 4 inches wide enclosed in plastic labeled with product name) proposed for use on this project.

5. The Manufacturer's material properties sheet (cut sheet) of the proposed geomembrane documenting that it shall meet or exceed specified requirements.

6. The Manufacturer's quality control certificates for raw resin material. Testing must be done in accordance with the Manufacturer's Quality Control (MQC) plan with a minimum of one test per lot and include tests listed in the table in Paragraph 2.01C.

7. The Manufacturer's quality control certificates for finished geomembrane. Testing must be done in accordance with the Manufacturer's QA/QC plan on the actual material to be shipped and include tests and frequencies performed as listed in the table in Paragraph 2.02G.

8. Written instructions for storing, handling, installing, seaming, and repairing proposed geomembrane, including recommendations for loading, unloading, and handling equipment (model number or load capacity) must be included.

9. Sample product warranty that meets the requirements of Article 1.05 and Section 01780, Warranties and Bonds.

10. The MQC plan, including examples of MQC certification documents, name and address of the quality control testing laboratory, quality control laboratory certification, examples of retesting notification, and documentation.

B. Product samples submitted shall be sent to the Construction Quality Assurance (CQA) Laboratory specified by the CQA Consultant unless otherwise noted or collected by the CQA Laboratory at the manufacturing plant. The sample package shall include a cover letter referencing the project location, CQA Consultant project number, the name of the manufacturer, the date of the sampling, and the lot and roll number. A copy of the cover letter shall be sent to the CQA Consultant.

C. CQA Samples: After reviewing the Manufacturer's certifications the CQA Consultant, the CQA Consultant, and/or the CQA Laboratory may visit the manufacturing plant and/or select product rolls to be sampled by the Manufacturer. The Manufacturer will then package and ship one 3-foot-long by the width of the roll sample at the frequencies specified for the material listed in Part 2 of this Specification. The sample will be tested in accordance with the requirements of the material listed in Part 2. In addition, the Manufacturer will package and ship a 3-foot-by-9-foot sample at the frequencies provided in this Section for a direct shear test to the CQA Laboratory's address for testing 21 days before shipping the product.

D. The Contractor shall be responsible for the cost of retesting should the CQA tests fail. The tests will be paid by the Owner and reimbursed by the Contractor as part of the project's final change order.

E. Project-Specific Product Acceptance Testing

1. After the CQA Consultant's review and approval of the Manufacturer's information, representative samples of the geomembrane product intended for this project and manufactured at the same plant that will produce the product for this project shall be sent to the CQA Laboratory for Project-Specific Product Acceptance Testing as listed in Article 2.02.

2. The CQA Consultant's acceptance of the geomembrane product proposed for use on this project will depend on the results of the Project-Specific Product Acceptance testing. Project-Specific Product Acceptance test results shall be submitted to the CQA Consultant 21 days before the geomembrane material is shipped to the project site. The geomembrane shall not be shipped before review and acceptance of the project-specific Product Acceptance Test results.

3. Product samples shall be sent to the Product Acceptance Laboratory specified by the CQA Consultant unless otherwise noted. The sample package should include a cover letter referencing the project location, CQA Consultant project number, Manufacturer, date of sampling, lot and roll number, and MQC test data documented for the particular production run from which the sample was taken. This submittal shall conform to the requirements of Section 01330, Submittals and Acceptance. A copy of the cover letter shall be sent to the CQA Consultant.

4. The Contractor shall bear the cost of all Project-Specific Product Acceptance Testing, including shipping samples to Product Acceptance Laboratory.

5. Geomembrane Samples: The Manufacturer shall package and ship two 3-foot-long by the width-of-roll-wide samples to the Product Acceptance Laboratory. The Manufacturer shall package the samples securely for shipping to prevent damage. The sampler shall mark the Manufacturer's roll identification number as well as the machine direction on the sample. The Contractor shall submit MQC data for the roll sampled with the test results.

6. If the results of any test do not conform to the requirements of this Specification, the Contractor may elect to retest from the same roll of product. The Contractor shall notify the CQA Consultant that a retest is planned. Retesting results shall be reported within 7 days. If the retest does not conform to the requirements of this Section, the product shall be rejected and the Contractor must submit Pre-Construction Submittals pertaining to the new product and perform Project-Specific Acceptance Tests for the new product.

F. Manufacturer's Quality Control

1. The MQC data shall be submitted at least 21 days before geomembrane shipment.

2. The Contractor shall submit the following:

   a. MQC test results to demonstrate that the geomembrane is in accordance with this Section.
   b. MQC sampling shall be in accordance with the test methods and minimum test frequencies provided in Article 2.02. If no sampling protocol is specified in the test method, then the samples shall be taken evenly spaced across the entire roll width in accordance with ASTM D4354.

3. Certification reports shall be submitted by the Manufacturer on the Manufacturer's letterhead and signed by an authorized representative of the Manufacturer.

4. MQC data shall be submitted electronically in PDF and data format (.xls, .xlsx, .csv, .txt, .doc, .docx, .accdb, etc.) that the data can be readily copied.

5. Provide the following information with MQC test data:

a. Project Name, Project Location, Manufacturer, Product Name.
b. Roll and lot numbers and any additional production identification.
c. Results of MQC tests, including a description of test methods used.

6. The Owner will reject rolls for which quality control requirements are not met.

7. If the results of any test do not conform to the requirements of this Specification, the Contractor may elect to retest from the same roll of product. The Contractor shall notify the CQA Consultant that a retest is planned. Retesting results shall be reported within 7 days. If the retest does not conform to the requirements of this Specification, the product shall be rejected and removed from the site.

1.03 REFERENCE STANDARDS

Reference standards and recommended practices referred to in this Specification Section shall be the latest revision of any such document in effect at the bid time. The following documents are a part of this Section. Where this Section differs from these documents, the requirements of this Section shall apply.

A. American Society for Testing and Materials (ASTM)

1. ASTM D792—Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
2. ASTM D1004—Test Method for Initial Tear and Resistance of Plastics Film and Sheeting.
3. ASTM D1238—Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
4. ASTM D1505—Standard Test Method for Density of Plastics by the Density-Gradient Technique.
5. ASTM D1557—Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
6. ASTM D1603—Standard Test Method for Carbon Black Content in Olefin Plastics.
7. ASTM D3895—Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.
8. ASTM D4218—Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
9. ASTM D4437—Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes.

10. ASTM D4833—Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.
11. ASTM D4873/D4873M—Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
12. ASTM D5199—Standard Test Method for Measuring Nominal Thickness of Geosynthetics.
13. ASTM D5321—Standard Test Method for Determining the Coefficient Of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
14. ASTM D5397—Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
15. ASTM D5596—Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
16. ASTM D5641—Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
17. ASTM D5721—Standard Practice for Air-Oven Aging of Polyolefin Geomembranes.
18. ASTM D5820—Standard Practice for Pressurized Air Channel Evaluation at Dual-Seamed Geomembranes.
19. ASTM D5885—Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.
20. ASTM D5994—Test Method for Measuring the Core Thickness of Textured Geomembranes.
21. ASTM D6392—Standard Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Produced using the Thermo-Fusion Methods.
22. ASTM D6497—Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures.
23. ASTM D6693—Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
24. ASTM D7466—Test Method for Measuring the Asperity Height of Textured Geomembranes.
25. ASTM E96—Standard Test Methods for Water Vapor Transmission of Materials.

B. Environmental Protection Agency (EPA)

1. EPA/600/R-93-182—Quality Assurance and Quality Control for Waste Containment Facilities.

C. Geosynthetics Research Institute (GRI) Standards

1. GM-10—The Stress Crack Resistance of HDPE Sheet.
2. GRI Test Method GM-13—Test Methods, Test Properties, and Testing Frequency for High-Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

1.04 QUALITY ASSURANCE

A. MQC is the responsibility of the Manufacturer to document that the material and installation are in accordance with this Specification.

B. The Owner will engage and pay for the services of a CQA Consultant. The Owner will engage and pay for the services of an independent CQA Laboratory for monitoring the quality of the geomembrane. The Manufacturer and Contractor shall help the Owner and the CQA Consultant with product sampling for CQA testing by providing samples, personnel, and equipment as necessary.

1. CQA tests shall be the measure of the acceptance of material. The Contractor shall be responsible for the cost of retesting if the CQA tests fail. The retests will be paid by the Owner and reimbursed by the Contractor.
2. Samples of geomembrane: After review of the project-specific Product Acceptance Test results, the CQA Consultant or representative may visit the manufacturing plant and/or select product rolls to be sampled by the Manufacturer. The Manufacturer will ship one 3-foot-long by the width-of-roll-wide sample for every 100,000 square feet of material to the CQA Consultant's CQA Laboratory for CQA testing. The sample package shall include a cover letter referencing the project location, project number, Manufacturer, date of sampling, lot and roll number, and MQC test data documented for the particular production run from which the sample was taken. A copy of the cover letter shall be submitted to the CQA Consultant.

1.05 WARRANTIES

A. Warranties shall be in accordance with General Conditions, and Specification Section 01780, Warranties and Bonds, and as specified in this Section.

B. The geomembrane Manufacturer's warranty, in writing, that the geomembrane material is guaranteed for 5 years on a pro rata basis from the date of Substantial Completion. This warranty shall apply to normal use and service in a landfill bottom liner (primary and secondary containment) application under exposure to

landfill leachate and landfill gas as well as other exposures that can be anticipated from the intended use.

1.06 DELIVERY, STORAGE, AND HANDLING

A. The Contractor shall adhere to the requirements specified in Section 01650, Delivery, Storage, and Handling, for delivering items specified in this Section. The Owner shall adhere to the requirements specified in Section 01650, Delivery, Storage, and Handling, for storing and handling items specified in this Section.

B. The Contractor shall conform to the Manufacturer's delivery requirements submitted in accordance with documents as required in Article 1.02 Manufacturer's Instructions.

C. The Manufacturer shall deliver materials to the site only after the CQA Consultant approves the required submittals.

D. Each roll of material shall have a Manufacturer's identification label. Each roll shall be labeled to provide product identification adequate for inventory and quality-control purposes. At a minimum, the label shall provide the Manufacturer's name, product identification, lot number, roll number, and roll dimensions. Rolls shall be labeled as specified in ASTM D4873/D4873M.

E. The Owner shall identify and separate damaged rolls from undamaged rolls and store damaged rolls at locations designated by the Owner. Rolls without proper labeling that identify roll number and dimensions will be considered damaged. Damaged material will be repaired or rejected at the discretion of the CQA Consultant. The cost of repair or replacement will be borne by the Owner.

1.07 QUALIFICATIONS

A. Provide the Manufacturer's qualifications in accordance with Article 1.02.

1.08 TESTING REQUIREMENTS

A. The Manufacturer shall provide samples for CQA testing in accordance with the requirements of this Section. Please refer to the material requirement and testing frequencies provided in this Specification.

B. CQA testing shall be performed for the material properties list in Part 2 of this Section. The cost of CQA testing shall be paid by the Owner.

1.09 DEFINITIONS

A. *Batch*: A quantity of resin, usually the capacity of one rail car, used in the fabrication of HDPE geomembrane sheet. A roll number corresponding to the particular quantity of resin used will identify the finished sheet.

B. *Extrudate*: The molten polymer emitted from an extruder during seaming using either extrusion fillet or extrusion flat methods. The polymer is initially in the form of a ribbon rod, bead, or pellets.

C. *Geomembrane*: An essentially impermeable membrane used as a solid or liquid barrier. Synonymous term for flexible membrane liner (FML).

D. *Geomembrane Manufacturer (Manufacturer)*: The party responsible for producing the geomembrane rolls from resin and for the quality of the resin.

E. *Lot*: A group of consecutively numbered rolls manufactured from the same resin batch or production line. For this Section a lot may not exceed 180,000 pounds of raw resin material.

F. *Manufacturing Quality Assurance* (MQA): A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits, and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. *MQA* refers to measures taken by the MQA organization to determine if the Manufacturer complies with the product certification and contract specifications for the project.

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

PART 2 PRODUCTS

2.01 GEOMEMBRANE RESIN

A. The geomembrane resin shall be virgin materials with no more than 10% reworked material from the same formulation as the parent material.

B. Do not add any post-consumer resin (PCR) of any type to the formulation.

C. Use materials meeting the following requirements unless otherwise approved:

Table 1 Geomembrane Resin Test Requirements		
Test	Test Designation	Requirements
1. Melt Index	ASTM D1238	< 1.0g /10 min
2. Specific Gravity	ASTM D1505 or D792 Method B	> 0.932 g/mL

2.02 PROPERTIES FOR TEXTURED HIGH-DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE

The Manufacturer shall ensure that the textured HDPE Geomembrane has the following properties:

A. Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and defects that would affect the specified properties of the geomembrane (GRI GM-13).

B. The geomembrane may not exceed a combined maximum total of 1% by weight of additives other than carbon black or pigment.

C. The geomembrane may not exceed 3.5% by weight of finished geomembrane for total combined processing aids, antioxidants, carbon black, and other additives.

D. All additives for UV protection, thermal stability, color, or processing agents must not "bloom" to the surface over time or inhibit welding.

E. The finished product must be free from blemishes, holes, pin holes, bubbles, blisters, excessive gels, undispersed resins and/or carbon black, contamination by foreign matter, as well as nicks or cuts on edges. The Manufacturer shall continuously perform spark tests during manufacturing to locate holes in the geomembrane. Repair holes before shipping as directed by the Engineer.

F. Roll manufactured sheets for shipment.

G. The geomembrane must conform to the following requirements in general accordance with GRI GM-13 (some requirements are stricter than GM-13):

Table 3 Geomembrane Test Requirements			
Test	Test Designation	MQC Test Frequency	Requirements
1. Sheet Thickness	ASTM D5994	Per roll	60 mils minus 15% for any measurement, minus 10% for 8 out of 10 individual values, and the average of all measurements for any roll, not less than 57 mils.
2. Asperity Height *(1)*	ASTM D7466	Every second roll *(1), (2)*	16 mils and as needed to meet shear-strength requirements
3. Sheet density	ASTM D1505 (preferred) or D792 Method B	1/50,000 sf	> 0.940 g/cc
4. Tensile Properties *(3)*			
a. Yield Strength	ASTM D6693 Type IV	1/50,000 sf	> 126 lb/in
b. Break Strength	ASTM D6693 Type IV	1/50,000 sf	> 90 lb/in
c. Yield Elongation	ASTM D6693, Type IV	1/50,000 sf	> 12% each sample
d. Break Elongation	ASTM D6693, Type IV	1/50,000 sf	> 100%
5. Tear Resistance	ASTM D1004, Die C	1/100,000 sf	> 42 lb
6. Puncture Resistance	ASTM D4833	1/100,000 sf	> 90 lb
7. Stress Crack Resistance *(4)*	ASTM D5397 (App.)	Per GRI GM10	> 500 hr
8. Carbon Black Content	ASTM D4218 *(5)*	1/50,000 sf	2.0 to 3.0%
9. Carbon Black Dispersion	ASTM D5596	1/100,000 sf	*(6)*
10. Standard Oxidation Induction Time of Polyolefins *(7)*	ASTM D3895 or ASTM D5885	One per formulation	Minimum average 100 minutes or Minimum average 400 minutes

(1) Of 10 readings, 8 out of 10 must be ≥ 14 mils, and lowest individual reading must be ≥ 12 mils; also see Note 6.

(2) Perform 10 readings on both sides of each roll if textured on both sides, one side if textured on one side.

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction. Yield elongation is calculated using a gauge length of 1.3 inches. Break elongation is calculated using a gauge length of 2.0 inches.

(4) P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the Manufacturer's mean value via MQC testing.

(5) Other methods such as D1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

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

(7) The Manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

2.03 MANUFACTURER SOURCE QUALITY CONTROL (MQC) TESTING

A. The Manufacturer shall perform the Manufacturer's quality control tests listed above.

B. Submit as indicated in Part 1 of this Section.

2.04 EXTRUDATE ROD OR BEAD

A. Made from same resin type as the geomembrane.

B. Containing 2% to 3% carbon black.

PART 3 EXECUTION (NOT USED)

END OF SECTION