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CONSTRUCTION QUALITY ASSURANCE FINAL REPORT

ON-SITE DISPOSAL FACILITY, PHASE II CELL 3

November 1999
Revision 0

United States Department of Energy

Fernald Environmental Management Project
Fernald, Ohio

Prepared by

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Under

Fluor Daniel Fernald
Subcontract 95PS005028

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1. INTRODUCTION

1.1 Terms of Reference

This final report summarizes the Construction Quality Control (CQC) and Construction Quality Assurance (CQA) activities performed by GeoSyntec Consultants (GeoSyntec) during the construction of the On-Site Disposal Facility (OSDF) Phase II Cell 3 project at the Fernald Environmental Management Project (FEMP), located near Fernald, Ohio. CQC and CQA activities performed by GeoSyntec will be collectively referred to as CQA activities in this report. The CQA activities performed by GeoSyntec included monitoring of: (i) soils construction; (ii) geosynthetics installation; and (iii) enhancement to the leachate conveyance system between manhole MH-3 and Cell 3. The CQA activities were performed to confirm that the construction materials, and construction and testing procedures, which were monitored and/or performed, were in compliance with the certified-for-construction drawings, technical specifications, CQA Plan and approved design changes notice (DCNs).

This report was prepared for Fluor Daniel Fernald (FDF) under Subcontract 95PS005028 by Dr. Kwasi Badu-Tweneboah, P.E. and Mr. Collin Sukow, both of GeoSyntec. The report was reviewed by Mr. James L. Burnett, also of GeoSyntec, in accordance with the company's peer review policy.

1.2 Background

The OSDF is a mixed low-level radioactive waste disposal facility dedicated to the FEMP that may, upon completion, cover approximately 90 acres (36 hectares) of landfill footprint. The OSDF is owned by Department of Energy (DOE) and is being constructed, filled, and operated by FDF as part of the overall remediation activities for the Fernald site.

DOE intends to build only one OSDF. Therefore, the OSDF is designed to accommodate all or any portion of the total volume of impacted material meeting the waste acceptance criteria (WAC) that results from remediation of the operable units. The total volume of material from all operable units is estimated to be 2.5 million bank/unbulked (i.e., in-place prior to excavation) cubic yards (1.9 million bank/unbulked cubic meters). The OSDF will be constructed over a period of time to be determined, depending on availability of funding.

The OSDF is being developed in several phases. The first year (1997) of construction included the OSDF Phase I lining system for Cell 1 and the leachate conveyance system projects. Construction of the Cell 1 lining system and the leachate conveyance system projects occurred between August and December 1997. A CQA Final Report for the OSDF Phase I Cell 1 lining system and the leachate conveyance system was prepared and issued by GeoSyntec in January 1998 [GeoSyntec, 1998a].

The second year (1998) of construction included the OSDF Phase II lining system for Cell 2 and placement of impacted material in Cell 1. Construction of the Cell 2 lining system occurred between June and November 1998. A CQA Final Report for the OSDF Phase II Cell 2 lining system was prepared and issued by GeoSyntec in December 1998 [GeoSyntec, 1998b]. Placement of impacted material in Cells 1 and 2 began in July 1998 and November 1998, respectively.

Cell 3 was constructed as part of the OSDF Phase II projects in 1999 and is the subject of this report. The Cell 3 construction consists of a double composite lining system of the same design as Cells 1 and 2 of the OSDF. Also included in this CQA Final Report are results of monitoring of the enhancement to the leachate conveyance system (i.e., the dual-containment piping system) between manhole MH-3 and Cell 3.

1.3 Report Organization

The remainder of this CQA Final Report is organized as follows.

- A description of the project is provided in Section 2.
- A description of the CQA program, including a summary description of specific tasks performed under the program, and a listing of project personnel, are presented in Section 3.
- A description of the CQA monitoring and testing activities performed during the earthwork portion of the project is provided in Section 4.

- A description of the CQA monitoring and testing activities performed during the geosynthetics installation is provided in Section 5.

- A description of the CQA monitoring and testing activities performed during enhancement to the leachate conveyance system between manhole MH-3 and Cell 3 is provided in Section 6.

- A summary of the observations resulting from the CQA monitoring, testing and documentation activities performed by GeoSyntec; and a certification statement verifying that OSDF Cell 3 was constructed in accordance with the Technical Specifications and Construction Drawings are presented in Section 7.

Documentation and record drawings presenting the results of the CQA monitoring and testing activities performed by GeoSyntec are contained in the appendices to this report. Weekly reports prepared by the CQA Site Manager and Resident Engineer are also included in the appendices. Daily reports prepared by the CQA monitors are not included in appendices; however, these daily reports can be made available on request.

2. PROJECT DESCRIPTION

The OSDF design incorporates a double-composite lining system and other engineering controls that meet the applicable or relevant and appropriate requirements (ARARs), DOE functional requirements, and general design criteria as described in the Design Criteria Package (DCP) developed and approved for the project during the design phase. The double-composite lining system at the base of the OSDF consists of the following components, from top to bottom:

- 1.0-ft (0.3-m) thick protective layer;
- 7-oz/ yd^2 (240-g/m^2) needlepunched nonwoven geotextile filter layer;
- 1.0-ft (0.3-m) thick leachate collection system (LCS) granular drainage layer;
- 10.0-oz/yd^2 (340-g/m^2) needlepunched nonwoven geotextile cushion layer;
- 80-mil (2.0-mm) thick high density polyethylene (HDPE) textured geomembrane component of a composite primary liner (hereafter referred to as primary liner geomembrane);
- a geosynthetic clay liner (GCL) component of the composite primary liner;
- 1.0-ft (0.3-m) thick leak detection system (LDS) granular drainage layer;
- 10-oz/yd^2 (340-g/m^2) needlepunched nonwoven geotextile cushion layer;
- 80-mil (2.0-mm) thick HDPE textured geomembrane component of a composite secondary liner (hereafter referred to as secondary liner geomembrane);
- a GCL component of the composite secondary liner;
- 3.0-ft (0.9-m) thick compacted clay liner component of the composite secondary liner; and

- varying thickness of prepared subgrade or compacted fill (hereafter referred to as subgrade).

The Cell 3 footprint has an approximately 750-ft (230-m) long by 365-ft (110-m) wide rectangular configuration and is located immediately south of Cell 2, and is bounded by intercell berms on the north and south. Cell 3 construction also includes a temporary termination to the lining system in the future Cell 4 footprint.

The leachate conveyance system was completed in 1997 and is operational. It is composed of a linear system of manholes and HDPE piping, a permanent lift station, and a force main designed and constructed to convey leachate from each of the OSDF cells to the advanced wastewater treatment facility. The leachate conveyance system was repaired in 1999 as part of a retrofit system [GeoSyntec, 1999a]. The only portion of the leachate conveyance system covered by this report is completion of the enhancement to the system from manhole MH-3 to Cell 3.

The Certified-For-Construction Drawings and Technical Specifications (dated November 1997) for the Phase II construction were prepared by GeoSyntec in accordance with the terms of FDF Subcontract 95PS005028, GeoSyntec Project Number GE3900. The prime contractor for construction of the OSDF Phase II Cell 3 project was Petro Environmental Technologies, Inc. (PETRO) of Cincinnati, Ohio. Installation of the geosynthetics components of the double-composite lining system for Cell 3 was performed by The Istre Company (Istre) of Glenpool, Oklahoma, as subcontractor to PETRO. The prime contractor for the enhancement to the leachate conveyance system from manhole MH-3 into Cell 3 was FDF Construction with assistance from Wise Construction Company (Wise) of Cincinnati, Ohio and Lee Supply Company, Inc. (Lee Supply) of Charleroi, Pennsylvania. The surveyor retained by PETRO for the OSDF Phase II Cell 3 project was Hirsch and Associates Surveying, Inc. (Hirsch). Surveying work associated with the enhancement to the leachate conveyance system was conducted by FDF. CQA monitoring, testing, and documentation was provided by GeoSyntec. A list of primary personnel involved in the OSDF Phase II Cell 3 project is included in Section 3.2 of this report.

As required by the project specifications, Hirsch surveyed the required layers of the lining system (i.e., subgrade, top of compacted clay, layout of secondary and primary liner geomembranes, top of LDS and LCS drainage layers, the invert of primary and secondary leachate collection pipes, and the top of the protective layer) and prepared the as-built drawings for the subgrade and top of each soil component of the lining system. GeoSyntec prepared the geomembrane record drawings.

Primary construction activities monitored by GeoSyntec's CQA personnel for the OSDF Phase II Cell 3 project included the following:

- rough grading of the cell floor (i.e., cut and fill operations);
- final preparation of the subgrade in excavation areas;
- placement of compacted fill material in fill areas;
- construction of the perimeter and intercell berms;
- construction of the compacted clay liner and clay wedge;
- installation of the liner penetration boxes;
- installation of the secondary and primary liner GCLs;
- installation of the secondary and primary liner geomembranes;
- installation of the geotextile cushion and filter layers;
- installation of the LDS drainage layer, LDS drainage corridor and pipes;
- installation of the LCS drainage layer, LCS drainage corridor and pipes; and
- placement of the protective layer.

Construction activities monitored by GeoSyntec's CQA personnel for the enhancement work on the leachate conveyance system from manhole MH-3 to Cell 3 included the following:

- trenching and excavation for the manhole and piping repair;

- placement and compaction of embedment fill and backfill for pipes, manhole and soil cover;
- replacement and welding of HDPE piping systems;
- hydrostatic and/or pneumatic testing of the HDPE piping systems;
- installation of temporary boxes around the manhole and cleanouts; and
- final grading.

The approval process for construction materials used during the OSDF Phase II Cell 3 project required the contractor and FDF to submit manufacturer's data, quality control certifications, and shop drawings to the FDF Construction Manager for review and approval. FDF was responsible for procurement of the geosynthetics. The FDF Construction Manager, FDF QA, FDF Engineering and the GeoSyntec Resident Engineer reviewed, commented (as needed), and approved construction materials for use during construction. The submittal details and approvals are summarized in the Resident Engineer's weekly reports presented in the appendices.

Earthwork construction associated with enhancement to the leachate conveyance system between manhole MH-3 and Cell 3 began on 02 August 1999 and was completed on 27 August 1999. Earthwork associated with OSDF Cell 3 construction began on 12 April 1999. Istre began and completed installation of the secondary liner geomembrane on 17 August 1999 and 11 September 1999, respectively. Istre began and completed installation of the primary liner geomembrane on 09 September and 25 September 1999, respectively. The construction of the OSDF Phase II Cell 3 lining system was completed on 20 October 1999, prior to beginning placement of protective layer material meeting the requirements of the Impacted Material Placement (IMP) Plan. Protective layer placement began on 12 October 1999 and was completed on 05 November 1999.

3. CONSTRUCTION QUALITY ASSURANCE PROGRAM

3.1 Scope of Services

3.1.1 Overview

The scope of CQA services performed by GeoSyntec during the OSDF Phase II Cell 3 project included:

- review of documents;
- monitoring, testing, and documentation of field operations; and
- preparation of the final report and record drawings.

These services are described in the following subsections of this report.

3.1.2 Review of Documents

As previously noted, this final report summarizes the CQA activities performed by GeoSyntec during the Phase II Cell 3 construction. The CQA activities performed by GeoSyntec were intended to satisfy the requirements of the following documents:

- "Technical Specification, OSDF Phase II," Revision 0, November 1997;
- "Technical Specifications, Leachate Conveyance System, OSDF," Revision 0, October 1996;
- "Construction Quality Assurance Plan, OSDF," Revision 0, May 1997;
- "OSDF Phase II," Construction Drawings, Revision 0, November 1997;
- "Leachate Conveyance System," Construction Drawings, Revision 0, August 1996; and
- "Impacted Material Placement Plan," Revision 0, January 1998.

During construction, design change notices (DCNs) were prepared which modified these documents. Documents containing the details of these DCNs are referenced in the appropriate sections of this report, and are included as an appendix to this report. Also included in the appendices are requests for clarification of information (RCIs) and nonconformance reports (NCRs). Only those documents relating to the completion of the enhancement to the leachate conveyance system between manhole MH-3 and Cell 3 and construction of Phase II Cell 3 lining system are provided in the appendices to this report.

The above documents (including the DCNs and RCIs) will be collectively referred to as the project documents in this final report. Prior to the commencement of on-site CQA activities, GeoSyntec's on-site CQA personnel reviewed for familiarity the project documents.

3.1.3 CQA Field Operations

The following activities were performed as part of GeoSyntec's on-site CQA services:

Earthwork:

- monitoring on-site borrow soils excavations;
- collecting conformance test samples of soils considered for use as compacted fill, compacted clay liner, and granular components of the leachate conveyance system and/or Cell 3 lining system for testing in either the on-site or off-site geotechnical laboratories;
- performing geotechnical conformance testing in field soils laboratory;
- reviewing and evaluating geotechnical laboratory conformance test results to ensure compliance with the requirements of the project documents;
- establishing acceptable permeability zones (APZs) for each clay stockpile;
- monitoring proofrolling and subgrade preparation;

- monitoring trenching operations for installation of the leachate conveyance system piping;
- monitoring placement and compaction of pipe and manhole embedment fill and backfill;
- monitoring grading operations (i.e., cutting and filling) on the cell floor;
- monitoring final preparation of the cell floor subgrade;
- monitoring placement and compaction of clay liner and perimeter berm
- testing of the in-place moisture/density of the compacted fill and compacted clay liner;
- monitoring surface of compacted clay liner for desiccation cracks prior to deployment of overlying secondary liner GCL;
- monitoring placement of the leachate collection and leak detection systems;
- verifying (by means of reviewing the surveyor's data, and/or observing the surveyor's survey stakes) that the elevations and the thicknesses of the soil layers are consistent with the project documents;
- monitoring placement of backfill in the perimeter anchor trench;
- monitoring protective layer placement; and
- monitoring placement and compaction of protective clay layer (i.e., clay wedge) above the anchor trenches and on the east and west perimeter berms.

Geosynthetics:

- tracking the inventory of geosynthetics materials (i.e., GCL, HDPE geomembrane, and geotextile rolls) delivered to the site;
- monitoring geosynthetics materials delivered to the site to observe whether the materials had been damaged during transportation or handling, and if so,

notifying FDF Quality Assurance and Construction Manager and marking damage for replacement or repair;

- collecting and reviewing geosynthetics manufacturers quality control documents to verify compliance with the requirements of the project documents;
- collecting geosynthetics conformance samples and forwarding samples to the off-site geosynthetics testing laboratory;
- reviewing and evaluating geosynthetics laboratory conformance test results to verify compliance with the requirements of the project documents;
- monitoring deployment and installation of geosynthetics materials and marking damage for replacement or repair;
- monitoring overlapping and direction of shingling of adjacent GCL panels;
- monitoring placement of granular bentonite between overlapping GCL panels;
- monitoring geomembrane trial seaming operations and field testing;
- monitoring geomembrane production seaming operations;
- monitoring nondestructive testing of the geomembrane seams;
- selecting geomembrane destructive seam sample locations, monitoring sample collection and field testing using a calibrated tensiometer, distributing destructive samples to the geosynthetics testing laboratory, and reviewing laboratory test results to verify compliance with the requirements of the project documents;
- monitoring the joining of adjacent geotextile panels;
- monitoring repairs to portions of the geosynthetics that were observed to have defects, or that failed destructive or nondestructive testing;

- monitoring electric leak detection testing of portions of the Cell 3 primary liner geomembrane; and
- monitoring the placement of the geosynthetics and the backfilling and compacting of compacted clay material in the anchor trench.

Leachate Collection and Leak Detection Systems (LCS and LDS):

- tracking the inventory of the liner penetration boxes and HDPE pipes;
- monitoring installation and field air pressure testing of liner penetration boxes;
- monitoring connection of the liner penetration boxes to the secondary and primary liner geomembranes;
- monitoring trial welds and production welding of HDPE pipes;
- testing of the in-place moisture/density of compacted pipe embedment material, and compacted fill for the leachate conveyance pipe;
- reviewing source qualification test results on samples of aggregate used in the LCS and LDS layer systems;
- monitoring deployment of the geotextile cushions;
- monitoring placement of the aggregate for the LCS and LDS layers;
- monitoring installation of the LCS collection pipe, LCS redundant pipe, LDS collection pipe, and LCS and LDS drainage corridor aggregate;
- monitoring joining of the perforated sections of the HDPE pipes to the solid-wall sections of the HDPE pipes from Cell 3 to manhole MH-3.
- monitoring replacement of the HDPE piping system from manhole MH-3 to Cell 3;
- visual monitoring of hydrostatic and pneumatic pressure testing of the leachate conveyance system pipes from Cell 3 to manhole MH-3; and

- monitoring of closed-circuit television (CCT) surveys of the LCS, redundant LCS and LDS carrier pipes from manhole MH-3 into Cell 3..

During construction activities involving monitoring and/or testing, the observations made and test results obtained by GeoSyntec CQA personnel were compared to the project documents. FDF and/or the appropriate contractor were notified of deficiencies in construction practices and/or materials so the contractor could take the appropriate corrective actions. The corrective actions were monitored and/or tested by CQA personnel to ensure compliance with the project documents.

Upon substantial completion of construction, testing and documentation of the OSDF Phase II Cell 3 project, an interim construction certification letter was prepared and submitted to FDF. A copy of the letter is included in Appendix A. This final certification report includes all construction required by the project documents except seeding of completed Cell 3 slopes. This will be completed as weather permits or as directed by FDF. Monitoring and documentation for this item will be included in either an addendum to this report or in the final certification report for future OSDF cell construction.

3.1.4 Final Report and Record Drawings

Record drawings and this final CQA report were prepared as the final task of the CQA program. This final report summarizes the CQA monitoring, testing, and documentation activities performed by GeoSyntec.

During construction, CQA personnel maintained documentation of on-site CQA activities. Daily documentation consisted of daily field reports and testing and monitoring logs. These documents were used to prepare weekly field reports, which are presented in Appendix C. CQA personnel also documented the results of on-site geotechnical laboratory testing and reviewed results of off-site geotechnical laboratory testing conducted as part of the CQA program. These are presented in Appendix F and Appendix G of this final report. In addition, manufacturer quality control (QC) certificates and test results for the geosynthetics materials were provided to GeoSyntec for review; these documents are included in Appendix H of this final report. Geosynthetics CQA conformance test results are also presented in Appendix I.

Surveyor's data were provided to GeoSyntec for review. The contractor's licensed surveyor prepared as-built drawings for the top of each soil layer in the lining system. GeoSyntec prepared geomembrane record drawings. The as-built and record drawings are included in Appendix S of this final report. Descriptions of the construction activities and the CQA documentation are presented in the narrative sections of this report.

Volume I of this CQA report contains the narrative sections of the report and Appendices A and B. Volume II of this report contains Appendices C through F; Volume III contains Appendices F (continued) through G; Volume IV contains Appendix H; Volume V contains Appendices I through Q; and Volume VI contains Appendices R through V. A summary of the documentation included in the appendices to the final report is provided below:

- Appendix A: Cell 3 Interim Construction Certification Letter
- Appendix B: Photographic Documentation.
- Appendix C: Weekly Field Reports
- Appendix D: Minutes of OSDF Weekly Construction Meetings
- Appendix E: Personnel Logs
- Appendix F: Geotechnical Laboratory Test Results
    - Compacted Fill
    - Compacted Clay Liner and Clay Wedge
        - Phase II Cell 2 (1998) Laboratory Testing
        - Phase II Cell 3 (1999) Laboratory Testing

APZ Curves Used for Cell 3 Construction
- Stockpile 98-13
- Stockpile 99-1
- Stockpile 99-2
- Stockpile 99-3
- Stockpile 99-4
- Stockpile 99-5

Pipe Embedment Fill
Granular Drainage Material

- Appendix G: Field Moisture/Density Test Results
  - Compacted Fill
  - Compacted Clay Liner and Clay Wedge
- Appendix H: Manufacturer's Quality Control Documentation
  - FDF/Manufacturer Submittals
    - Geosynthetic Clay Liner
    - Geomembrane
    - Geotextile
  - Contractor/Installer Submittals
    - Geosynthetics
    - Granular Drainage Material
    - Liner Penetration Boxes
    - HDPE Pipes
    - Testing Equipment Calibration
    - Installer's Qualifications and Resumes
- Appendix I: Geosynthetics Conformance Test Results
  - Geosynthetic Clay Liner
  - Hydraulic Conductivity Test Results
  - Direct Shear Test Results
  - Geomembrane
  - Geotextile
- Appendix J: Contractor's Certificate of Acceptance of Subgrade
  - Secondary

Primary

- Appendix K: Geomembrane Panel Placement Monitoring Logs
  - Secondary
  - Primary
- Appendix L: Geomembrane Trial Seam Logs
  - Fusion
  - Extrusion
- Appendix M: Geomembrane Production Seam Logs
  - Secondary
    - Fusion
    - Extrusion
  - Primary
    - Fusion
    - Extrusion
- Appendix N: Geomembrane Destructive Seam Test Logs and Laboratory Test Results
  - Secondary
  - Primary
- Appendix O: Geomembrane Repair Summary Logs
  - Secondary
  - Primary
- Appendix P: Geomembrane Seam and Panel Repair Location Logs
  - Secondary
  - Primary
- Appendix Q: Electric Leak Detection Testing Report (Draft)
- Appendix R: Enhancement to Leachate Conveyance System Test Logs
  - HDPE Pipe Welding

Butt Fusion
Extrusion Welded Sleeves
Pressure Test Results
Cell 3
Manhole MH-3
Contractor Test Reports

- Appendix S: As-Built and Geomembrane Record Drawings
  - As-Built Drawings
    - Top of Subgrade
    - Top of Compacted Clay Liner
    - Top of Leak Detection Layer
    - Top of Leachate Collection Layer
    - Top of Protective Layer
  - Geomembrane Record Drawings
    - Secondary
    - Primary
- Appendix T: Requests for Clarification of Information (RCIs)
- Appendix U: Design Change Notices (DCNs)
- Appendix V: Nonconformance Reports (NCRs)
  - GeoSyntec Consultants
  - Fluor Daniel Fernald

3.2 <u>Personnel</u>

3.2.1 Project Personnel

Senior personnel or representatives for the firms involved in the project are as follows:

Fluor Daniel Fernald (Owner's Representative)

- Charles D. Brown, Safety & Health
- J. D. Chiou, Ph.D., P.E., Project Manager
- Robert D. Crowley, Radiological Field Support

- Bill D. Edmondson, Construction
- Jeffrey R. Ellis, Construction Engineer
- Donald A. Fleming, Industrial Hygiene
- David Fox, CADD Operator
- Michael W. Godber, QA/QC Team Leader
- Donald B. Goetz, Construction Engineer
- Kevin S. Harbin, Construction Engineer
- Mathew C. Harper, Construction Engineer
- Richard A. Holbrook, Contracts and Acquisition Team Leader
- David W. (Warren) Hooper, Construction Team Coach
- James C. Jenkins, P.E., D.E.E, Engineering
- Gregg K. Johnson, Safety & Health Team Leader
- Anthony P. Klimek, P.E., Engineering
- Uday A. Kumthekar, P.E., Engineering Team Coach
- Christine M. Messerly, Environmental Compliance
- Jeffrey A. Middaugh, Safety & Health
- Gregory R. Peters, Construction Engineer
- Bruce A. Schweitzer, Construction Engineer
- Daniel H. Stempfley, Radiological Engineering
- Phillip G. Thomas, Safety & Health
- Robert M. Turnbull, Construction Engineer
- James T. Turner, Quality Assurance Engineer
- Charles C. VanArsdale, P.E., Engineering
- Muriel K. Vigus, Quality Assurance
- Paul J. Volker, Quality Assurance
- Louis R. Wehlitz, Construction Team Leader
- Samuel H. Wolinsky, P.E., Engineering
- William A. Zebick, OSDF Construction Manager

GeoSyntec Consultants (CQA Consultant)

- K. Badu-Tweneboah, Ph.D., P.E. Resident/Certifying Engineer
- J. F. Beech, Ph.D., P.E., Program Manager
- D. G. Bodine, P.E., Special Assistant
- J. L. Burnett, Project Manager
- D. K. Phillips, P.E., Project Coordinator
- S. Quammen, Site Safety and Health Officer
- C. P. Sukow, CQA Site Manager

GeoSyntec's Geomechanical, Environmental and Materials (GEM) Testing Laboratory (off-site geotechnical laboratory)

- N. Rad, Ph.D., P.E., Laboratory Manager
- B. Sigmon, Program Manager/Quality Control Manager

GeoSyntec's Soil-Geosynthetic Interaction (SGI) Testing Laboratory (off-site soil-geosynthetic interaction testing)

- R. Swan, Jr., Laboratory Manager
- Z. Yuan, Jr., Ph.D., Quality Control Manager

GeoTesting Express, Inc (off-site geosynthetics testing laboratory)

- G.T. Torosian, Laboratory Manager

Hirsch and Associates (Contractor's Surveyor)

- Lynn E. Hirsch, P.L.S., President and Owner

Petro Environmental Technologies, Inc. (PETRO) (Contractor, senior personnel only)

- Pete Bolig, Project Manager
- Carl Ketchem, Safety & Health Manager
- Jeff Browning, Field Superintendent
- Jim Haitz, Safety & Health Officer
- Jill Hibbard, Project Administrator
- Ike Robinson, Labor Foreman
- David Williams, Operations Manager
- Ira Rogers, General Superintendent

- Rick Schairbaum, QA/QC Manager
- Chris Tucker, Project Engineer
- Steve Bremer, QC Inspector
- Brian Erisman, QC Inspector

The Istre Company (Geosynthetics Installer)

- Jerry Istre, Superintendent
- Ron J. Scott, QC Chief
- Louis L. Luna, Master Seamer

3.2.2 GeoSyntec's On-Site Personnel Schedules

GeoSyntec project personnel were present on site according to the following schedules:

• J. F. Beech, Ph.D., P.E., Program Manager	05 May, 14-15 Jun, and 17-18 Aug 1999
• J. L. Burnett, Project Manager	08 Mar - 07 Nov 1999
• K. Badu-Tweneboah, Ph.D., P.E., Resident/Certifying Engineer	10 Mar – 02 Apr, 16-23 Apr, 03-29 May, 07 June – 15 Jul, 02 Aug – 07 Nov 1999
• D. K. Phillips, P.E., Project Coordinator	15-18 Sep, 27-30 Sep, 03-04 Nov 1999
• D. G. Bodine, P.E., Special Assistant	08 Mar – 02 Apr, 26-29 Apr, 14-18 May, 01-03 Jun, 17-18 Jun, 26-30 Jul, 15 Sep, 20 Oct 1999
• Dennis Vander Linde, P.E., Project Engineer	14 Jun, 03-04 Nov 1999
• C. P. Sukow, CQC Site Manager	08 Mar – 11 Oct 1999
• Dave Evans, Engineering Technician	08 Mar – 02 Jul, 14 Jul –07 Nov 1999
• T. Byran York, Senior Engineering Technician	08 Mar – 26 Apr, 06 Jul –07 Nov 1999
• Scott Quammen, Senior Engineering Technician	08 Mar – 07 Nov 1999
• Mike Humphreys, Engineering Technician	02 May – 07 Nov 1999
• Tony Dickman, Engineering Technician	19 Jul – 07 Nov 1999
• Rob Peddicord, Engineering Technician	09-26 Mar, 03 May – 07 Sep, 22 Sep – 07 Nov 1999
• Rodney Hummel, Engineering Technician	10 Mar – 18 Jun 1999
• Renee Erisman, Administrative Assistant	08 Mar – 07 Nov 1999

4. CONSTRUCTION QUALITY ASSURANCE – EARTHWORK

4.1 General

GeoSyntec monitored the construction of the earthwork components associated with the OSDF Phase II Cell 3 project. The OSDF Phase II project components completed during 1999 consisted of Cell 3 lining system construction and development of the clay borrow area. Different earthwork materials were used to construct the various components of the projects. These materials included existing subgrade material, compacted fill, compacted clay liner, granular drainage material for the LDS and LCS layers, and pipe embedment fill material. The earthwork construction activities using these materials are generally described below.

- Cell 3 subgrade was initially rough graded. The subgrade surface was proofrolled by using a loaded articulated dump truck and visually monitored by CQA personnel. Isolated areas of soft or loose materials were either dried and compacted or undercut and replaced with fill material which was compacted as described below.

- The cell floor was graded to achieve the required subgrade elevations. The subgrade in areas of the cell floor that required filling were proofrolled prior to fill placement to detect excessively soft or loose zones. Soft or loose zones were excavated prior to placement of fill. The fill material consisted of compacted fill, which was obtained from cut areas in the cell, or other on-site borrow sources within the construction area. The compacted fill was placed in approximately 7- to 12-in. (180- to 305-mm) thick (maximum) loose lifts and compacted to a minimum degree of compaction of 95 percent of the maximum dry density (MDD), as determined by the standard Proctor compaction test (i.e., American Society for Testing and Materials (ASTM) D 698). The fill was compacted at a moisture content between 3 percent dry and 3 percent wet of the optimum moisture content (OMC) measured in the standard Proctor compaction test.

- The Cell 3 perimeter berms were also constructed using compacted fill. The fill was placed in approximately 8-in. (200-mm) thick (maximum) loose lifts and compacted as described above.

- The 3-ft (0.9-m) thick compacted clay liner for Cell 3 was constructed using 8-in. (200-mm) thick (maximum) loose lifts; with the exception of the first lift which was placed as a 10-in. (200-mm) thick loose lift. This initial 10-in. (200-mm) thick loose lift resulted in a compacted lift thickness of about 6 in. (150 mm) when measured to the bottom of the pad foot indentation, and about 2-in. (50-mm) of material between compactor foot indentations. (This latter material was included in the second lift.) The compacted clay material was obtained from the east field borrow area. Each lift was compacted to a minimum degree of compaction of 95 percent of the MDD, as determined by the standard Proctor compaction test (ASTM D 698). The compacted clay liner was compacted at a moisture content between zero and 3 percent wet of the OMC measured in the standard Proctor compaction test. The field moisture content and dry unit weight were also required to fall within the acceptable permeability zone (APZ) as established by the Test Pad Program Final Report (TPPFR) and the TPPFR Addendum, and defined in the Technical Specifications and DCN No. 20102-079. The APZ criteria were used to assure a hydraulic conductivity of less than 1×10^{-7} cm/s. Clay materials used in the compacted clay liner were approved through conformance testing which included hydraulic conductivity testing of remolded compacted clay samples on composites from each stockpile in the off-site geotechnical laboratory and establishment of an APZ for each clay stockpile..

- The granular components of the Cell 3 lining system, which included a 1-ft (0.3-m) thick LDS layer and a 1-ft (0.3-m) thick LCS layer were constructed using material obtained from off-site borrow sources. Each material was placed in one loose lift. Granular drainage materials were approved through conformance testing of samples and review of supplier's certification test results.

- The compacted clay layers for the clay wedges were constructed using 9-in. (200-mm) thick (maximum) loose lifts. Each lift was compacted to a minimum degree of compaction of 95 percent of the MDD, as determined by the standard Proctor compaction test (ASTM D 698). The clay wedge layers connecting the cell clay liner and future clay cap were compacted at field moisture contents and dry unit weights falling within the APZ as established by the TPPFR and the TPPFR Addendum, and defined in the Technical Specifications and DCN No. 20102-079. The APZ criteria were used to assure a hydraulic conductivity of less than 1×10^{-7} cm/s. Clay materials used in the compacted clay wedges were clay liner material approved through conformance testing which included hydraulic conductivity testing of remolded compacted clay samples on composites from each stockpile.

CQA personnel observed these earthwork construction activities and tested the soil materials to confirm that the material properties conformed to the project documents, that the specific lift thicknesses were not exceeded, and that the materials were placed and compacted in accordance with the project documents. Geotechnical soil tests were performed and documented by CQA personnel. The testing was carried out either: (i) in-place; (ii) on-site, in the geotechnical laboratory; or (iii) off-site, at GeoSyntec's GEM Testing Laboratory in Alpharetta, Georgia.

4.2 Changes in Earthwork Specifications

RCIs and DCNs of the earthwork drawings and specifications were processed and approved according to procedures described in FEMP Document No. ED-12-5002 titled "Engineering Design Change Process". RCIs and DCNs were approved, as appropriate by the design organization. Copies of the RCIs and DCNs for Phase II Cell 3 project are presented in Appendices T and U, respectively.

4.3 Conformance Activities

Soil samples were obtained from proposed sources, prior to construction, to verify conformance with the project specifications for each material type. Also during construction, soil samples were obtained from the delivered material as required by the project documents. CQA personnel obtained representative samples of compacted fill, compacted clay liner material, and granular drainage layer materials from the appropriate source depending on the material type.

Compacted fill material used in Cell 3 construction was obtained from on-site borrow areas within active OSDF construction areas. Compacted clay liner material was obtained from the on-site east field borrow area located south of the OSDF area. The granular drainage material was obtained from an off-site source. The LCS and LDS drainage layer (No. 78 stone) was obtained from Highland Stone Quarry located in Hillsboro, Ohio. The LCS and LDS drainage corridor material (No. 57 stone) was obtained from Watson Gravel Quarry located in Ross, Ohio.

In accordance with the project documents, a series of geotechnical tests were performed on the soil samples to confirm that the following requirements were met:

- Compacted fill material used in construction classified as GC, SC, SM, ML or CL according to the Unified Soil Classification Systems (USCS) when evaluated in accordance with ASTM D 2487 and the maximum particle size was 5.0 in. (130 mm). Compacted fill was also used to backfill the excavations for the enhancement to the leachate conveyance system from manhole MH-3 to the Cell 3 perimeter berm.

- Compacted clay liner material used in construction was classified as lean clay (CL) or fat clay (CH) according to the USCS when evaluated in accordance with ASTM D 2487; had a maximum particle size of 2.0 in. (50 mm); had not less than 50 percent of the particles, by weight, passing through the U.S. No. 200 standard sieve; had not less than 15 percent of the particles, by weight, having a maximum dimension greater than 0.002 mm; a plasticity index (PI) between 10 and 40 when tested in accordance with ASTM D 4318; and hydraulic conductivity (i.e., permeability) of 1.0×10^{-7} cm/s or less, when evaluated in accordance with ASTM D 5084. The perimeter berm anchor trench backfill material had the same requirements as the compacted clay liner material.

- The granular drainage material used in construction of the LCS and LDS layers was classified as GP according to the USCS when evaluated in accordance with ASTM D 2487; had 100 percent passing a 0.75 in. (19 mm) opening sieve when tested in accordance with ASTM C 136; generally met gradation requirements for No. 78 stone (except for three samples as indicated in Table 4-3); had a carbonate content of less than or equal to 5 percent when tested in accordance with ASTM D 3042 at a pH of 4; and the hydraulic conductivity (i.e., permeability) requirement was 0.1 cm/s or greater when evaluated in accordance with ASTM D 2434.

- The granular drainage material used in construction of the LCS and LDS drainage corridors classified as GW or GP according to the USCS when evaluated in accordance with ASTM D 2487; had 100 percent passing a 1.5 in. (38 mm) opening sieve when tested in accordance with ASTM C 136; generally met gradation requirements for No. 57 stone (except for one sample as indicated in Table 4-4); had a carbonate content of less than or equal to 5 percent when tested in accordance with ASTM D 3042 at a pH of 4; and the hydraulic conductivity (i.e., permeability) requirement was 10 cm/s or greater when evaluated in accordance with ASTM D 2434.

A description of the geotechnical tests and results are described in Section 4.5 of this report. Construction of the perimeter berm anchor trench is described in Section 4.6.2 of this report.

4.4 Field Monitoring Activities

4.4.1 General

GeoSyntec's CQA personnel monitored the placement of soil as previously described. Potentially nonconforming or questionable practices observed by CQA personnel were brought to the attention of the Construction Manager for review and correction.

4.4.2 Excavation

CQA personnel monitored excavation operations within Phase II Cell 3 work areas. Topsoil, organic matter (i.e., stumps, roots, or vegetation), and any other deleterious material unsuitable for subgrade material was excavated and stockpiled on-site prior to construction of the lining system.

4.4.3 Compacted Fill

CQA personnel monitored the placement of the compacted fill for the cell floor, perimeter berms, and other areas requiring fill material. Areas receiving fill and areas that were cut to subgrade elevations were proofrolled by the contractor to detect soft or loose zones. Proofrolling was performed using a loaded articulated dump truck. In areas where soft or loose materials were detected, the areas were undercut and compacted fill was placed. In cut areas and during proofrolling, the surface was monitored by CQA personnel to confirm that deleterious materials were removed. In areas where the fill was extended from previous construction of Cell 2, the previously compacted fill was cut back, in order to establish a key-in, prior to the construction of the extension for Cell 3.

The compacted fill material was placed in controlled lifts (as described previously) using articulated dump trucks and using a Caterpillar D-6R bulldozer to spread the material. The horizontal lifts were then compacted using a Caterpillar 815 padfoot compactor. When there was inclement weather which impacted the exposed lift of compacted fill, prior to further placement of subsequent lifts, the surface of the top lift was scarified using the tracks of a bulldozer.

4.4.4 Compacted Clay Liner

After completing the compacted fill grading operations, CQA personnel observed the placement and compaction of the clay liner material. Construction of the compacted clay liner was performed in accordance with the project documents and patterned after the Test Pad Program. Two compacted clay liner test pads were constructed prior to the construction of the Cell 1 compacted clay liner. The results of the test pad program were used to develop the specifications for compacted clay liner materials and construction. The test pad program is described in a report entitled "Test Pad Program Final Report", Revision 0, dated June 1997. A "Test Pad Program Final Report Addendum No. 1", Revision 0, dated January 1999 modified the left boundary of the APZ from the 90% degree of saturation line to a line defined by the "line of optimums" for the clay liner material in use. This modification was approved and implemented for Cell 3 construction through DCN No. 20102-079. This modified APZ was established for each stockpile that was used for the Cell 3 compacted clay liner construction.

The construction sequence of the compacted clay liner is described below:

- after stripping the topsoil at the source, the clay was processed on-site using a bar screening plant and stockpiled in preparation for transportation to the cell construction site;

- each clay material stockpile had an established APZ based on geotechnical laboratory testing;

- a water bar attachment on the screening plant added water to the material to increase the moisture content, as needed;

- the cell floor surface and the top surface of each lift of compacted clay was scarified using a soil stabilizer; the sideslopes of the cell and top surface of each lift of compacted clay on the sideslopes was scarified with the tracks of a Caterpillar D-6R bulldozer;

- the compacted clay material was hauled from the stockpile by articulated dump trucks and placed in the cell;

- the compacted clay was spread in approximately 7- to 8-in. (180- to 200-mm) thick (loose) lifts using a D-6R bulldozer;.

- after spreading, a RACO 250 soil stabilizer was used to break up clods of compacted clay; water was added to increase the compacted clay's moisture content as required;

- after each lift was stabilized using the soil stabilizer, visible rock particles greater than 2 in. (50 mm) in size were removed by laborers;

- each lift of compacted clay was compacted using a Caterpillar 825 padfoot compactor making a minimum of six passes;

- lift thickness was controlled for the first lift by grade stakes placed by the contractor at an approximate spacing of 50 ft (15 m); CQA personnel visually monitored the placement and compaction of the compacted clay relative to these stakes to provide a check of lift thickness; the stakes were removed immediately before the material adjacent to the stakes was compacted; subsequent lifts were visually monitored by the contractor using traffic cones for grade control;

- a D-6R bulldozer was used to grade the compacted clay material;

- the final grade was rolled with a vibratory smooth drum roller to seal the top surface of the compacted clay; and

- after final grading of the compacted clay surface, the surveyor confirmed final grade elevations.

The contractor periodically added water during or after compacted clay placement to limit drying or desiccation cracking of the compacted clay surface. Prior to deployment of the overlying GCL, the compacted clay liner was visually observed by the installer and CQA personnel for surface cracks. If significant drying or cracking of the compacted clay surface was observed, the contractor was instructed to moisture condition and rework the affected area.

4.4.5 Leak Detection System Layer

CQA personnel monitored the placement of the LDS layer for Cell 3. The 1-ft (0.3-m) thick LDS layer was constructed using granular drainage material obtained from Highland Stone. The method of placement and the CQA procedures during construction of the LDS layer were similar to the methods and procedures used during construction of the LCS layer, discussed below.

It is noted that the same material was used in the LDS drainage layer as the LCS layer, which is discussed in Section 4.4.6. In addition, a leachate collection pipe was installed in the LDS drainage corridor. The pipe was surrounded by LDS drainage corridor aggregate, which was obtained from Watson Gravel.

4.4.6 Leachate Collection System Layer

CQA personnel monitored the placement of the LCS drainage layer and corridor material for Cell 3. The 1-ft (0.3-m) thick LCS layer was constructed using granular drainage material obtained from Highland Stone. The granular drainage material was stockpiled in an area south of the Cell 3 construction area. The LCS drainage corridor material was constructed using granular drainage material obtained from Watson Gravel. The granular drainage material was stockpiled in an area south of the Cell 3 construction area.

The construction sequence of the LCS layer was as follows:

- Volvo articulated dump trucks hauled the granular drainage material from the stockpile to the cell area using a minimum 3-ft (0.9-m) thick haul road constructed of LCS material;

- the granular drainage material was spread in approximately one 1-ft (0.3-m) thick (loose) lift using Caterpillar D-6R LGP wide-track bulldozers; and

- a contractor's laborer was utilized during the spreading operation to control and prevent wrinkle formation in the underlying geosynthetics.

During placement of the LCS layer, CQA personnel monitored the contractor's activities to assure that geomembrane wrinkling and the risk of damage to the underlying geomembrane was minimized. CQA personnel also checked that the contractor operated bulldozers in areas where at least a 1-ft (0.3-m) thick layer of granular drainage material was maintained over the geomembrane, and that a 3-ft (0.9-m) thick layer of granular drainage material was maintained over the geomembrane in heavily trafficked areas.

In addition, leachate collection pipes (LCS and redundant LCS pipes) were installed in the LCS drainage corridor. The pipes were surrounded by LCS drainage corridor aggregate.

4.4.7 Protective Layer

CQA personnel monitored the placement operations for the protective layer. The protective layer within the Cell 3 footprint was constructed using impacted material obtained from on-site Active Fly-Ash Stockpile. In the impacted runoff catchment area, however, non-impacted granular material meeting the requirements of the LCS drainage layer material was used to construct the 1-ft (0.3-m) thick protective layer. Non-impacted clayey soil was also used to construct the protective layer on the outside slopes of the Cell 3/Cell 4 intercell berm.

The protective layer was placed in a 12- to 15-in. (300- to 380-mm) thick loose lift and was tracked with a Caterpillar D-6R LGP bulldozer. A minimum 3-ft (0.9-m) thick haul road constructed of protective layer material was used by the dump trucks for placement of material into the cell. CQA personnel checked that the minimum 3-ft (0.9-m) thick protective layer material was maintained in heavily trafficked areas within the cell.

4.5 Field Testing Activities

4.5.1 Geotechnical Testing

As part of CQA activities, geotechnical testing was performed on each of the soil components of the Cell 3 double composite lining system. Testing was performed in-place or at either the on-site or off-site geotechnical laboratory. The following geotechnical tests were performed.

- In-place nuclear moisture/density tests were performed on compacted lifts of compacted fill and compacted clay liner and clay cap material. The tests were performed in general accordance with ASTM D 2922 and ASTM D 3017.

- Standard Proctor compaction tests were conducted on the soils used for compacted fill and compacted clay liner material. The tests were performed in general accordance with ASTM D 698. Modified Proctor compaction tests were also performed on the clay liner material in general accordance with ASTM D 1557. The standard and modified Proctor compaction tests were used to establish the "line of optimums" for each clay material stockpile as part of the modified APZ.

- Moisture content tests were performed on samples of compacted fill and compacted clay liner material. The tests were performed in general accordance with ASTM D 2216.

- Particle-size distribution tests were conducted on the soils used for compacted fill and compacted clay liner material. The tests were performed in general accordance with ASTM D 422. Atterberg limits tests were conducted on the soils used for compacted clay liner material. The tests were performed in general accordance with ASTM D 4318. The USCS was used to classify the materials in accordance with ASTM D 2487.

- Carbonate content tests and hydraulic conductivity tests were conducted on the LCS and LDS drainage layers and LCS and LDS drainage corridor material. The tests were performed in general accordance with ASTM D 3042 and ASTM D 2434, respectively.

- Hydraulic conductivity tests were performed on the compacted clay liner material. Tests were conducted on remolded individual and composite samples of processed clay liner material from each stockpile. The hydraulic conductivity tests on compacted clay liner material were conducted in general accordance with ASTM D 5084. The results of the hydraulic conductivity tests on composite samples were used to verify the established APZ for each clay material stockpile.

A summary of the results of the geotechnical laboratory tests is presented in Appendix F. The results of the in-place nuclear moisture/density tests are presented in Appendix G. GeoSyntec supplied two nuclear gauges (i.e., Troxler models 3430 and 3440) for Cell 3 construction, which were used to perform the moisture/density tests for Phase II construction. The results of the nuclear moisture/density tests were verified periodically, by comparing the tests with results obtained using the drive cylinder method (ASTM D 2937) and with oven moisture content tests. A moisture correction factor based on nuclear and oven moisture content tests was developed for compacted clay liner material during Cell 2 construction. The data are presented in Appendix G and was used to support the field density test data during Cell 3 construction. Additional oven moisture content samples were taken during Cell 3 construction and the data were compiled with Cell 2 samples for use in future clay liner and cap construction.

A grid layout of the site was used to visually locate the in-place tests and sample locations. Only visual positioning of test locations was used. Therefore, the locations and elevations (if given) of the tests and samples reported in the appendices are approximate.

4.5.2 Compacted Fill

Compacted fill was compacted to a minimum degree of compaction of 95 percent of the maximum dry unit weight, as determined by the standard Proctor compaction test. CQA personnel conducted in-place nuclear moisture/density tests at a minimum frequency of 2 tests per acre (5 tests per hectare) per lift of soil. A total of 68 field moisture/density tests were performed in the Cell 3 area. Of these, 7 tests failed to meet the minimum percent compaction requirement. In each case of a failing test, the contractor reworked and recompacted the area surrounding the failure and then CQA personnel retested the area. This procedure was repeated until satisfactory moisture/density test results were obtained in each location. The results of the field moisture/density tests are presented in Appendix G.

In addition to the in-place testing, 5 representative samples were obtained for laboratory testing during construction. A summary of the testing requirements is presented in Table 4-1. Geotechnical test results are presented in Appendix F.

4.5.3 Compacted Clay Liner/Clay Wedge

CQA personnel performed in-place nuclear moisture/density tests at a minimum frequency of 5 tests per acre (12 tests per hectare) per lift of the Cell 3 compacted clay liner/clay wedge. A total of 442 field moisture/density tests were performed. A total of 55 tests failed to meet the minimum degree of compaction requirement of 95 percent of the maximum dry unit weight at less than 3 percent over optimum moisture content, as determined by the standard Proctor compaction test and within the APZ. For each failed test the contractor reworked and recompacted the area surrounding the failure and then CQA personnel retested the area. This procedure was repeated until satisfactory moisture/density test results were obtained. The results of the field moisture/density tests are presented in Appendix G. The holes left from the moisture/density tests, were filled with bentonite granules and compacted clay material. The mixture was manually compacted in the holes using a steel rod.

As part of the CQA activities for the compacted clay liner and clay wedge, CQA personnel periodically checked the moisture content in the clay stockpile.

Off-site geotechnical laboratory hydraulic conductivity tests were performed on remolded individual and composite samples of the clay liner material from each stockpile. The composite samples were obtained on a minimum frequency of one per stockpile or one per 10,000 yd^3 (7,600 m^3) of clay liner material, in accordance with the TPPFR Addendum and authorization by the Construction Manager. A copy of the Construction Manager's authorization on the sampling and testing frequency is included in Appendix F. It should be noted that the TPPFR Addendum, which was used to establish the modified APZ for Cell 3 liner construction, recommends that stockpiles be developed in 5,000 to 10,000 yd^3 (3,800 to 7,600 m^3) volumetric capacity. As a result of the TPPFR Addendum and Construction Manager's authorization, a total of five remolded hydraulic conductivity tests were performed on five composite samples with each sample being representative of each clay material stockpile. The sample from clay material stockpile 99-4 failed to meet the hydraulic conductivity criterion of 1×10^{-7} cm/s or less when remolded within the modified APZ. A detailed investigation revealed that clay material stockpile 99-4 would only meet the hydraulic conductivity criterion of 1×10^{-7} cm/s or less when remolded within the APZ defined by the 90% degree of saturation line, which was the previous APZ used for Cells 1 and 2 construction. Therefore, RCI No. 20102-054R (see Appendix T) was issued to allow clay stockpile 99-4 to be used with a restricted APZ, which lies within the modified APZ. The laboratory test results are presented in Appendix F. A summary of compacted clay liner/clay wedge properties is presented in Table 4-2.

In addition to the geotechnical testing described above, index tests were performed on the clay material as required by the project documents. Index tests were performed at a minimum frequency of one set per 1,500 yd^2 (1,150 m^2) of stockpiled material. A total of 33 particle-size distribution tests and 33 Atterberg limits tests were performed on the compacted clay liner material to verify that the consistency of the material corresponded to the requirements of the Technical Specification. The tests indicated a variation in the plasticity index between 10 and 40. The tests also indicated a minimum clay content of 15 percent. The particle-size distribution and Atterberg limits tests all resulted in a classification of CL for the clay liner material, according to the USCS. The results of these tests are presented in Appendix F.

Following confirmation of the test results, and prior to deployment of the GCL and geomembrane liner, the surface of the compacted clay liner was visually observed by the installer and CQA personnel for surface cracks. If significant drying or cracking of the surface was observed, the contractor was instructed to moisture condition and rework the affected area.

TABLE 4-1

COMPACTED FILL MATERIAL PROPERTIES SUMMARY CELL 3

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM D 422	100% Finer than 5.0 in.	1 per 1,500	2	5
Compaction	ASTM D 698	---	1 per 1,500/ as required	2	5
Moisture	ASTM D 2216 ASTM D 4643	---	1 per 1,500/ as required	2	2
Soil Classification	ASTM D 2487	GC, SC, SM, ML or CL	1 per 1,500	2	2
Atterberg Limits	ASTM D 4318	---	1 per 1,500	2	2
FIELD TEST					
Drive Cylinder Soil density Soil moisture	ASTM D 2937 ASTM D 2216	... ...	1 per 25 passing density tests	3	4
Nuclear Gauge: Soil density Soil moisture	ASTM D 2922 ASTM D 3017	≥95% MDD ± 3% OMC	2/acre/lift	40 (separate lifts)	68 (7)

NOTES: (1) Reference Section 02200 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 2,000 yd^3 for the Phase II Cell 3 construction.

TABLE 4-2

COMPACTED CLAY LINER PROPERTIES SUMMARY
CELL 3

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size:	ASTM D 422		1 per 1,500	28	
Sieve					
Percent Finer than 2.0 in.		100%			33
Percent Finer than 0.75 in.		≥90%			
Hydrometer					
Percent Finer than No. 200	ASTM D 1140	≥50%			33
Percent Finer than 0.002 mm		≥15%			
Compaction	ASTM D 698/ ASTM D 1557	---	1 per 1,500/ as required	28/14	34/22
Moisture	ASTM D 2216 ASTM D 4643	---	1 per 1,500/ as required	28	66
Soil Classification	ASTM D 2487	CL or CH	1 per 1,500	28	33
Atterberg Limits	ASTM D 4318	$10 \leq PI \leq 40$	1 per 1,500	28	33
Hydraulic Conductivity:	ASTM D 5084	$\leq 1 \times 10^{-7}$ cm/s	1 per 10,000 or 1 per stockpile		
Individual samples (Remold)				7	9
Composite samples (Remold)				5	5
FIELD TEST					
Drive Tube:		---	1 per 25 passing density tests	16	18
Soil density	ASTM D 2937				
Soil moisture	ASTM D 2216				
Nuclear Gauge or Drive Cylinder	ASTM D2992	Within APZ and	5/acre/lift	280	442 (55)
Soil density	ASTM D 2937	≥ 95% MDD			
Soil moisture	ASTM D 3017	0 - 3% OMC			
Depth Verification					
Survey	Visual	As shown on drawings	--	--	--

NOTES: (1) Reference Section 02225 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a stockpile volume of 42,659 yd^3 (from the Contractor's tonnage of processed clay material) for the Phase II Cell 3 construction.

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4.5.4 Leak Detection System Layer

The 1.0-ft (0.3-m) thick LDS layer was constructed using granular drainage material. The material was spread on top of the geotextile cushion overlying the secondary liner geomembrane. This layer of the lining system had the same CQA requirements as the LCS layer, discussed in Section 4.5.5.

GeoSyntec personnel performed on-site laboratory and off-site laboratory geotechnical testing on the granular drainage material used for the LDS layer as part of the CQA activities during Cell 3 construction. These tests were identical to those for the LCS layer, as described in Section 4.5.5.

Particle-size distribution tests were performed on representative samples obtained from the on-site stockpiles. GeoSyntec also performed off-site laboratory permeability tests and carbonate tests on representative samples of the granular drainage material. A summary of the testing requirements for granular drainage material for the drainage layer is presented in Table 4-3. A summary of the testing requirements for granular drainage material for the drainage corridor is presented in Table 4-4. Geotechnical laboratory test results are presented in Appendix F.

4.5.5 Leachate Collection System Layer

The 1.0-ft (0.3-m) thick LCS layer was constructed using granular drainage material. The material was spread on top of the geotextile cushion overlying the primary liner geomembrane as previously described in Section 4.4.6. It is noted that this material was also used in the LDS layer that was discussed in Section 4.5.4.

GeoSyntec performed on-site and off-site geotechnical laboratory testing on the granular drainage material used for the LCS and LDS layers as part of the CQA activities during Cell 3 construction. On-site and off-site laboratory particle-size distribution tests were performed on nine (9) samples obtained from the on-site stockpile. The LCS and LDS drainage layer material was classified as a GW or GP, based on the USCS. The laboratory particle-size distribution test results are presented in Appendix F.

GeoSyntec also performed off-site laboratory hydraulic conductivity tests and carbonate content tests on representative samples of the granular drainage material. A summary of the testing requirements for granular drainage material for the drainage layer is presented in Table 4-3. A summary of the testing requirements for granular drainage material for the drainage corridor is presented in Table 4-4. Geotechnical laboratory test results are presented in Appendix F.

4.5.6 Protective Layer

The 1-ft (0.3-m) thick protective layer was constructed using impacted material as described in the Impacted Material Placement (IMP) Plan. The material was spread on top of the LCS geotextile filter overlying the LCS granular drainage material.

To protect the underlying geosynthetics from construction damage, the protective layer was not compacted with conventional compaction equipment but was tracked with a Caterpillar D6-R LGP bulldozer.

CQA personnel monitored transporting, placing, tracking and final surveying of the protective layer to verify conformance with the IMP Plan and the CQA Plan. CQA personnel signed the manifests and documented that placement was in accordance with the IMP Plan and CQA Plan.

4.6 Soil Anchorage of Geosynthetics

4.6.1 General

GeoSyntec's CQA personnel monitored the placement of material for anchorage of the geosynthetics material around the perimeter of the cell. Compacted clay liner material was used to provide the permanent anchorage of the geosynthetics. Details of the anchoring are presented in Sections 4.6.2 and 4.6.3 below.

TABLE 4-3

LCS AND LDS DRAINAGE LAYER GRANULAR MATERIAL (NO. 78 STONE) CELL 3

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM C 136	3/4 in. 100 1/2 in. 80-100 3/8 in. 40-75 No. 4 5-25 No. 8 0-10 No. 16 0-5 No. 200 0-2	1 per 3,000	8	9 (3)[3]
Soil Classification	ASTM D 2487	GP	1 per 3,000	8	9
Carbonate Content	ASTM D 3042	≤5%	1 per 5,000	5	6
Hydraulic Conductivity: Granular	ASTM D 2434	≥ 0.1 cm/s	1 per 3,000	8	9
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	--	--	--

NOTES: (1) Reference Section 02710 of the Specification and Section 6 of the CQA Plan for further details.

(2) The approximate number of tests required is based on a total volume of 24,000 yd^3 for the Cell 3 construction.

(3) The three (3) tests failed to meet the gradation specifications in one sieve size only. These failures were resolved through disposition of non-conformance reports (NCRs) presented in Appendix V.

TABLE 4-4

LCS AND LDS DRAINAGE CORRIDOR GRANULAR MATERIAL (NO. 57 STONE) CELL 3

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM C 136	1 1/2 in. 100 1 in. 95-100 1/2 in. 25-60 No. 4 0-10 No. 8 0-5 No. 200 0-2	1 per 3,000	1	2 (1)[3]
Soil Classification	ASTM D 2487	GP	1 per 3,000	1	2
Carbonate Content	ASTM D 3042	≤ 5%	1 per 5,000	1	1
Hydraulic Conductivity: Granular	ASTM D 2434	≥ 10 cm/s	1 per 3,000	1	1
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	---	---	---

NOTES:
(1) Reference Section 02710 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 1,700 yd^3 for the Cell 3 construction.
(3) The one (1) test failed to meet the gradation specifications in one sieve size only. This failure was resolved through disposition of an NCR presented in Appendix V.

4.6.2 Perimeter Anchor Trenches

As required by the project documents, anchor trenches were constructed around the east and west perimeters of the Cell 3 construction area. The construction sequence of the perimeter anchor trenches were as follows:

- a 2-ft (0.6-m) wide by 2-ft (0.6-m) deep anchor trench was excavated along the Cell 3 perimeter berm, approximately 3 ft (0.9 m) from the crest of the slope;
- the secondary liner system geosynthetics (i.e., GCL, geomembrane liner, and geotextile cushion) were subsequently placed in the anchor trench and lifts of compacted clay material were placed over these material and compacted;
- a 2-ft (0.6-m) wide by 2-ft (0.6-m) deep anchor trench was excavated along the Cell 3 perimeter berm, approximately 7 ft (2.1 m) from the crest of the slope; and
- the primary liner system geosynthetics (i.e., GCL, geomembrane liner, and geotextile cushion) were placed in the anchor trench behind the secondary liner system geosynthetics, and lifts of compacted clay material were placed into the anchor trench and compacted.

The general construction procedure for placing and compacting the clay material in the perimeter anchor trenches was as follows:

- backfill material was obtained from the processed stockpile and placed in the trenches using a backhoe;
- backfill material was placed in the anchor trench for the first lift in 10- to 12-in. (250- to 300-mm) thick (loose) lifts and in subsequent lifts in approximately 6-in. (150-mm) thick loose lifts; and
- the backfill material was compacted using a walk behind articulated pad roller.

Anchor trench backfill was compacted at a moisture content between 0 and 3 percent wet of the OMC and to a minimum 95 percent degree of compaction of the MDD, as determined by the standard Proctor compaction test (ASTM D 698). Nuclear moisture/density tests were performed on the compacted clay material in the anchor trench. A summary of the results of the compaction tests and the field moisture/density tests are included in Appendix G.

5. CONSTRUCTION QUALITY ASSURANCE - GEOSYNTHETICS

5.1 General

GeoSyntec monitored the installation of the geosynthetics components of the double-composite lining system. Principal field activities are summarized in Section 3.1.3. Non-conforming or questionable practices observed by CQA personnel were brought to the attention of the FDF Quality Assurance and the Construction Manager for review and correction.

The total quantity of geomembrane installed during the Phase II Cell 3 construction, as measured by CQA personnel, was 575,950 ft^2 (53,510 m^2), which consists of the primary liner geomembrane and secondary liner geomembrane, including the anchor trenches. The panel layout record drawings for the primary liner and secondary liner geomembranes are presented in Appendix S.

5.2 Changes in Geosynthetics Specifications

RCI and DCN of the geosynthetics drawings and specifications were processed and approved according to procedures described in FEMP document number ED-12-5002 entitled "Engineering Design Change Process." These RCIs and DCNs were approved, as appropriate, by the design organization. Copies of the RCIs and DCNs issued for Phase II Cell 3 are presented in Appendices T and U, respectively.

5.3 CQA of Geosynthetic Clay Liner

5.3.1 Conformance Testing and Documentation

A geosynthetic clay liner (GCL) was used in construction of the double composite liner system. Rolls of the Bentomat ST GCL, manufactured by Colloid Environmental Technologies Company (CETCO) in Lovell, Wyoming were used for the Cell 3 lining system construction.

For the Bentomat ST GCL, nine (9) samples (Nos. GCL 99-1 through GCL 99-9) from GCL Lot No. 199922020 were collected for conformance testing. Two representatives from FDF and one representative from GeoSyntec visited the CETCO plant in Lovell, Wyoming to observe production, review procedures, and sample material on 25-26 May 1999. All of the 9 Bentomat ST conformance samples were obtained at the factory prior to shipment of materials. The sampling frequency exceeded the minimum acceptable sample frequency of one per 100,000 ft^2 (9,300 m^2) required by the project documents.. Conformance samples were forwarded to GeoSyntec's GEM Testing Laboratory for hydraulic conductivity testing and to GeoSyntec's SGI Testing Laboratory for direct shear testing. Based on the conformance sampling and testing results, including the supplier's testing, the lot stated above was approved for construction.

The conformance test results and the manufacturer's quality control (QC) certificates were reviewed by design personnel. A summary table for Cell 3 GCL approval is presented in Table 5-1. The manufacturer's QC documentation is presented in Appendix H. GeoSyntec's conformance test results are also presented in Appendix I. A summary of the physical properties of the GCL and the conformance test frequency is presented in Table 5-2.

TABLE 5-1

GEOSYNTHETIC CLAY LINER (GCL) CONFORMANCE TESTING APPROVAL SUMMARY CELL 3

LOT No.	CQA Roll No. [1]	MQC Roll No. [2]	CQA Test Results	MQC Test Results	Roll Nos. Approved for Construction	Date [3] Approved	No. of Rolls [4]	Square Footage [5]
199922020	5360	5358/5335	Pass	Pass	5323-5364	07 Jul 99	42 Total	94,500
199922020	5322	5320/5291	Pass	Pass	5279-5322	07 Jul 99	43 Total	96,750
199922020	5278	5276/5247	Pass	Pass	5236-5278	07 Jul 99	43 Total	96,750
199922020	5235	5232/5203	Pass	Pass	5196-5235	13 Jul 99	40 Total	90,000
199922020	5195	5188/5159	Pass	Pass	5152-5195	15 Jul 99	44 Total	99,000
199922020	5142	5144/5115	Pass	Pass	5108-5151	03 Aug 99	44 Total	99,000
199922020	5098	5100/5072	Pass	Pass	5064-5107	03 Aug 99	44 Total	99,000
199922020	5055	5056	Pass	Pass	5033-5063	06 Aug 99	31 Total	69,750
199922020	5002	5012	Pass	Pass	5002-5016	12 Aug 99	15 Total	33,750

Notes:
1. CQA Roll No. is roll used for conformance testing (direct shear and permeability).
2. MQC Roll No. is roll used for manufacturer's QC testing (direct shear and permeability).
3. Date given is date GeoSyntec conformance testing approved. Manufacturer's tests were approved at later date.
4. Number of rolls given is total delivered to site and used in Cell 3 construction.
5. Square footage for total number of rolls given.

000053

TABLE 5-2

GEOSYNTHETIC CLAY LINER PHYSICAL PROPERTIES SUMMARY
CELL 3

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS[3]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY[5] (ft^2)	
				Manf. QC	Conformance QA
Bentonite Content (lb/ft^2)	ASTM D 5993	1.0 lb/ft^2 @ 25% moisture	≥ 1.0	40,000	NA
Bentonite Moisture Content (%)	ASTM D 4643	25% max	≤ 25	40,000	NA
Direct Shear[4]	ASTM D 5321	NA	LD Shear - 12° LD Shear - 7° LD Shear - 6.5° Peak Shear - 17°	100,000	100,000 or per lot
Grab Elongation (%)	ASTM D 4632	10 % Typical	NA	40,000	NA
Peel Strength (lb/in)	ASTM D 4632	15 min	≥ 15 lb/in	40,000	NA
Grab Strength (lb)	ASTM D 4632	90 MARV	NA	40,000	NA
Hydraulic Conductivity (cm/s) (σ' = 5 psi)	ASTM D 5887	$\leq 5x10^{-9}$	$\leq 5x10^{-9}$	100,000	100,000
Fluid Loss (ml)	ASTM D 5891	18 max	≤ 18 ml	40,000	NA
Bentonite Free Swell (ml/2g)	ASTM D 5890	24	≥ 24	40,000	NA

Total No. of Bentomat ST Rolls Delivered to Site: 346 Total No. of Conformance Samples: 9

Notes:
(1) Reference Section 02772P of the Specifications and Section 8 of the CQA Plan for further details.
(2) Ambient placement temperatures are between 40°F and 104°F. The GCL rolls are overlapped a minimum of 6 in. along edges, with a 24 in. end overlap. No horizontal seams are allowed on the slopes (≥5H:1V). Patches extend 12 in. beyond a defect on ≤5% slope areas and 24 in. on ≥5% slope areas. Granular bentonite is placed between seams involving Bentomat ST.
(3) Bentomat ST is the GCL used for Cell 3. Roll dimensions are 15 ft by 150 ft.
(4) Peak Shear Strength and Large-Displacement (LD) shear strength at normal stress of 5, 20, 45 psi, reported as Secant Angle in degrees.
(5) Testing shall be performed at a frequency of one per lot or at listed frequency, whichever is greater. A lot is defined by ASTM D 4354.
MD - Machine Direction; XD - Cross-Machine Direction; NA - Not Applicable; σ' = Effective Confining Stress.

5.3.2 Field Monitoring Activities

5.3.2.1 Delivery and On-Site Storage

Upon delivery, GCL rolls were unloaded in a laydown area located in the southeast corner of the future Cell 4 construction area and covered with a tarpaulin. The GCL rolls had a plastic wrapping to protect against water and premature hydration. An all-terrain lift truck or a front-end loader transported the rolls. The rolls were temporarily stored adjacent to the construction area prior to deployment. CQA personnel periodically monitored the installer's delivery, unloading, and storage procedures. Potentially nonconforming or questionable practices observed by CQA personnel were brought to the attention of the Construction Manager for review and correction. The CQA personnel observed that the material was stored and handled in an appropriate manner or corrective action was taken, where appropriate.

5.3.2.2 Deployment

CQA personnel monitored the deployment of the GCL rolls. During deployment, the CQA personnel checked for the following:

- manufacturing defects;
- evidence of premature hydration of the bentonite;
- damage that may have occurred during shipment, storage, and handling; and/or
- damage resulting from installation activities.

If materials were observed to be damaged, the installer was notified and the damaged materials were either discarded or repaired. CQA personnel observed repair locations, during and after repair.

CQA personnel monitored the deployment of the GCL, as well as its condition after installation, to verify that the installer followed the following procedures:

- prior to deployment, the installer signed a Certificate of Acceptance of subgrade (presented in Appendix J);

- the GCL was unrolled and placed in a manner which kept the roll of GCL in sufficient tension to avoid excessive wrinkling using low ground-pressure rubber-tracked equipment;

- the rolls were deployed with the geotextile printed with the manufacturer's name facing upwards (i.e., woven geotextile up and nonwoven geotextile in contact with the underlying soil component);

- measures were taken to avoid entrapment of stones or other objects in the GCL panels;

- measures were taken to avoid damage to the underlying clay surface during deployment of the rolls;

- measures were taken to keep the GCL free of contamination and protected from premature hydration; and

- geomembrane installation immediately followed installation of the GCL.

After deployment of the GCL, CQA personnel observed that the adjacent rolls of GCL were joined using the following procedures:

- adjacent GCL panels were shingled in the direction of the slope to prevent the potential for runoff flow to enter the overlapped panel;

- adjacent GCL panels were overlapped a minimum of 6 in. (150 mm) along the length of the panels and a minimum of 24 in. (600 mm) along the width of the panels; and

- dry bentonite granules was applied around liner penetration boxes and between seams of overlapped panels in accordance with the GCL manufacturer's recommendation.

Observed holes or tears in the GCL were repaired by the installer by placing a patch of the same material over or under the hole or tear and at a distance of at least 2 ft (0.6 m) beyond the edges of the hole on slopes greater than 5 percent or 1 ft (0.3 m) beyond the edges of the hole or tear on slopes less than 5 percent. In areas where premature hydration of the GCL was detected, the GCL was removed and replaced with new approved material.

5.4 CQA of Geomembrane

5.4.1 Conformance Testing and Documentation

The 80-mil (2.0-mm) thick textured HDPE geomembrane was supplied by GSE Lining Technology, Inc, Houston, Texas. Prior to Cell 3 construction, geomembrane conformance samples were taken randomly from the 80-mil (2.0-mm) thick HDPE textured geomembrane rolls used to construct the lining system. A total of nine (9) conformance samples were obtained by CQA personnel at the manufacturing plant prior to delivery to the site. These samples represented 3 lots of geomembrane, which comprised 83 geomembrane rolls. The total number of conformance samples exceeds the minimum acceptable sample frequency of one per 100,000 ft^2 (9,300 m^2) or one per lot as required by the project documents.

The conformance samples were forwarded to GeoTesting Express, Inc. for testing. The conformance test results and the manufacturer's QC certificates, for each roll, were reviewed by CQA personnel and were found to be in compliance with the project documents. The geomembrane manufacturer's QC documentation included resin and geomembrane certifications and is presented in Appendix H. The geomembrane manufacturer's roll numbers, GeoSyntec's conformance sample logs, and GeoTesting Express' conformance test results are presented in Appendix I. A summary of the physical properties of the geomembrane and the conformance test results are presented in Tables 5-3.

In addition to geomembrane conformance testing, the project documents specified a manufacturer's certification letter of conformance for the extrudate rod. CQA personnel obtained one letter of certification for the extrudate rod during construction of Cell 3. The certification letter is presented in Appendix H.

5.4.2 Field Monitoring Activities

5.4.2.1 Delivery and On-Site Storage

Upon delivery to the site, geomembrane rolls were stored in a laydown area located to the southeast of future Cell 4 construction area. The rolls of geomembrane had nylon straps, which were used to lift the rolls. The rolls were transported by a front-end loader. Occasionally, the rolls were temporarily stored adjacent to the construction area prior to deployment. CQA personnel periodically monitored the delivery, unloading, and storage procedures. The CQA personnel compared the roll numbers to the geomembrane rolls that were sampled at the manufacturer's plant and also to the bill of lading. The CQA personnel observed that procedures were used that minimized the potential for damage to the rolls.

5.4.2.2 Deployment

The geomembrane rolls were lifted using a spreader bar attached to a front-end loader. An LGP rubber tracked vehicle was used in the deployment of geomembrane panels over the previously installed GCL panels using procedures approved by the Construction Manager to assure no damage to the GCL. The installer generally deployed the geomembrane panels from: (i) south to north across the Cell 3/Cell 4 intercell berm; and (ii) east to west across the cell floor and in accordance with the approved panel layout drawing. The installer used laborers to manually position the panels.

CQA personnel monitored the deployment of each geomembrane panel or roll. During deployment, the CQA personnel checked for the following:

- manufacturing defects;
- damage that may have occurred during shipment, storage, or handling; and/or

- damage resulting from installation activities, including damage as a consequence of panel placement, seaming operations, or weather.

If the materials were observed to be damaged or deficient, the installer was notified and the damaged materials were either discarded or repaired. CQA personnel observed repair locations, either during or after the repair were complete.

Details of the geomembrane panel placement were recorded by CQA personnel on the panel placement monitoring logs that are presented in Appendix K.

5.4.2.3 Trial Seams

Prior to production seaming, the installer prepared geomembrane trial seams at the beginning of each seaming period, and at least once each five hours, for each seaming equipment used that day prior to seaming. Also, each seamer prepared at least one trial seam each day that seaming was performed by that seamer using a specific piece of seaming equipment. CQA personnel observed the trial seaming operations. The following procedure was used to evaluate the trial seams:

- trial seam samples varying in length from 3 to 15 ft (0.9 to 4.5 m) and having a width of approximately 12 in. (0.3 m) wide were welded under similar conditions as for production seaming;

- test strips were cut across the trial seam at random locations using a manual dye press; each test strip was approximately 1 in. (25 mm) wide by 8 in. (200 mm) long;

- two test strips were tested in peel and two were tested in shear using a field tensiometer;

- the passing criteria for the tests were as follows:

Fusion

- *Peel test* - a minimum bonded seam strength of 115 lb/in. (15 kN/m) and the observation of a Film Tearing Bond (FTB), and

- *Shear test* - a minimum bonded seam strength of 151 lb/in. (23 kN/m); and the observation of a FTB;

Extrusion

- *Peel test* - a minimum bonded seam strength of 84 lb/in. (13 kN/m); and the observation of a FTB, and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (21 kN/m); and the observation of a FTB;

- if any of the strips failed, corrective actions to the welding procedure were implemented, a new trial seam was fabricated, and the test procedure repeated; passing tests in both peel and shear were achieved prior to acceptance of the trial seam; if these retest strips failed, the welder and/or the equipment were rejected until the problem was corrected and two consecutive passing trial seams were completed; and
- once a trial seam passed both tests, the technician was authorized to proceed with production seaming following the procedures and controls used to prepare the accepted trial seams.

A total of 178 trial seams were observed by CQA personnel during Cell 3 construction. A total of 82 trial seams were made using double-track fusion (i.e., hot wedge) welders and 96 were made using extrusion welders. A total of 6 trial seams failed (4 fusion seams and 2 extrusion seams). In the case of a failing test, the retesting protocol described above was followed or the equipment was not used.

Trial seam samples were not archived. The trial seam test results are presented in Appendix L.

5.4.2.4 Production Seams

Geomembrane production seaming operations were monitored by CQA personnel. The majority of the geomembrane production seams were fabricated using double-track fusion (i.e., hot wedge) welders. Geomembrane seam repairs were made using hand-held extrusion welders. During or after fabrication, the geomembrane seams were visually examined for workmanship and continuity. Geomembrane production seaming logs are presented in Appendix M.

A cold weather seaming plan was submitted by the installer in the event ambient temperatures dropped below 40°F (5°C). However, the cold weather seaming specifications were not implemented during the Cell 3 construction season. Production seaming activities were not performed below 40°F (5°C) during the Cell 3 construction project.

5.4.3 Nondestructive Seam Testing

5.4.3.1 Scope

Nondestructive testing of geomembrane seams was periodically monitored by CQA personnel. Geomembrane seams were nondestructively tested by the installer for continuity using the air pressure or the vacuum-box test procedures. Double-track fusion seams were tested using air pressure test methods. The vacuum-box test method was used for seams made with extrusion welders. Failed air pressure test seams were capped and retested using vacuum-box test methods after minimizing the failed seam length. Leaks identified using the vacuum-box method were repaired and retested, as described in Section 5.4.5 of this report.

5.4.3.2 Air Pressure Testing

Accessible double-track fusion seams were nondestructively tested using the air pressure test. The procedure used by the installer for air pressure testing was as follows:

- CQA personnel visually observed the integrity of the annulus of the section of seam being tested;
- a test section was isolated by sealing the ends of the annulus using heat and pressure;

- the needle of a pressure test apparatus was inserted into the annulus at one end of the seam;
- the annulus was inflated to a gauge pressure of approximately 25 to 30 psi (170 to 200 kPa) with an air pump;
- the gauge pressure was maintained for at least five minutes;
- if the pressure loss exceeded 3 psi (23 kPa), or if the pressure did not stabilize, the faulty area was repaired in accordance with Section 5.4.5 of this report;
- the location of the test was recorded along with the testing pressures; and
- upon completion of the test, airflow through the entire annulus was confirmed by releasing the air from the seam at the opposite end from where the needle was inserted.

Geomembrane air pressure test logs are presented in Appendix M.

5.4.3.3 Vacuum-Box Testing

The vacuum-box was used by the installer to nondestructively test extrusion seams and repairs. The procedure used by the installer for vacuum testing was as follows:

- vacuum-box assembly was connected to the vacuum pump;
- a strip of seam was wetted with a soapy solution;
- the vacuum-box assembly was placed over the wetted area;
- the bleed valve was closed and the vacuum valve was opened, if necessary;
- the box was forced onto the sheet until a vacuum was established as evidenced by a negative box pressure of approximately 5 psi (34 kPa);

- the seam was examined through the viewing window for a period of approximately 20 seconds for the occurrence of air bubbles;

- the location of any leaks were recorded;

- the vacuum valve was closed and the bleed valve was opened, if necessary; and

- the assembly was removed and the process was continued along the seam.

On the fusion-welded seams (i.e., tie-in seams, butt seams) that were not air pressure tested, the installer trimmed the overlap and vacuum box tested the seam. When nondestructive testing indicated repairs were necessary, repairs were made in accordance with procedures presented in Section 5.4.5 of this report and the vacuum-box testing repeated. Vacuum test logs are presented in Appendix M.

5.4.4 Destructive Seam Sample Testing

5.4.4.1 Scope

In accordance with the CQA Plan, CQA personnel identified and collected geomembrane seam samples for destructive testing. The samples were forwarded to GeoTesting Express, Inc. for destructive seam testing.

A total of 67 geomembrane seam sample locations were identified during Cell 3 construction; 33 passing and 3 failing tests on the secondary liner geomembrane and 34 passing and 10 failing tests on the primary liner geomembrane. Approximately 31,885 linear ft (9,725 linear meters) of seams were constructed. This corresponds to an approximate sample frequency of one per 475 linear feet (145 linear meters) of seam. This frequency meets the minimum acceptable sample frequency of one per 500 linear feet (150 linear meters) required by the CQA Plan. Prior to the removal of a full seam sample, the installer took two geomembrane test strips from either end of the destructive sample. Each strip was tested in the field in peel. If the peel samples exhibited a FTB failure mode and minimum required strength, the adjacent destructive seam sample was shipped to the laboratory for testing.

For a destructive seam sample to be considered as passing, the following seam strength criteria had to be met on four out of the five tests performed on each of the destructive seam specimens obtained from each of the destructive seam samples. In addition, a non-FTB was considered to exhibit more than 10 percent seam separation.

Fusion

- *Peel test* - a minimum bonded seam strength of 115 lb/in. (15 kN/m) and the observation of a FTB; and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (23 kN/m); and the observation of a FTB;

Extrusion

- *Peel test* - a minimum bonded seam strength of 84 lb/in. (13 kN/m); and the observation of a FTB; and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (21 kN/m); and the observation of a FTB;

In addition, if more than one non-FTB failure (i.e., greater than or equal to 10 percent seam separation) was observed, the destructive seam sample was considered to have failed.

5.4.4.2 Sampling Procedures

At each destructive seam sample location, a test sample that measured approximately 12 in. (300 mm) across the seam and 42 in. (1.1 m) along the seam was obtained. The sample was divided and distributed as follows:

- 12 in. (300 mm) wide by 12 in. (300 mm) long for owner's archives;
- 12 in. (300 mm) wide by 12 in. (300 mm) long for the installer; and
- 18 in. (500 mm) wide by 12 in. (300 mm) long for CQA laboratory testing.

5.4.4.3 Test Results

Off-site laboratory testing of geomembrane seam test samples was performed in accordance with the CQA Plan at the GeoTesting Express, Inc. Testing Laboratory. In the laboratory, 1-in. (25-mm) wide test specimens were removed from the destructive seam sample using a die press. On a gauged tensiometer, five test specimens were tested in peel for adhesion. For fusion seams, tests were performed on both the inside track and on the outside track. Additionally, five specimens were tested for shear strength. The seam-strength criteria and the acceptance/rejection criteria described in Section 5.4.4.1 were used.

For Cell 3, 13 failures were recorded on the initial destructive samples; 8 failures occurred in the field test strips and 5 failures occurred in the laboratory destructive samples. In each case, the failed area was isolated by selecting additional test-strip locations at a minimum distance of 10 ft (3 m) on either side of the failure. If the additional test strips had passing results, a full destructive seam sample was taken. These destructive seam samples were tested in accordance with procedures previously described in this section. Twenty-four (24) additional seam samples were obtained to isolate failures and on reconstructed seams; 17 on the primary liner geomembrane and 7 on the secondary liner geomembrane. Seams having failing destructive samples were repaired using procedures presented in Section 5.4.5. The destructive seam test sample locations were also repaired using the procedure presented in Section 5.4.5. The destructive seam test results and a summary of the number of samples obtained are presented in Appendix N.

5.4.5 Geomembrane Repairs

The procedures presented in this subsection were used by the installer during the following repair operations:

- patching holes and tears;
- capping failed seams;
- spot-extruding impact damage or other minor scratches; and

- grinding and extrusion welding small sections of failed fusion seams (if the exposed edge was accessible).

The repair procedure for fusion seams, was to cap strip the failed seam. This procedure was used for seams with insufficient overlap and used for failing destructive tests.

In the cases where patches or caps were used to repair the damaged geomembrane (i.e., small holes, tears, or on seams which failed nondestructive or destructive tests), an approximately 12 in. (300 mm) wide capping strip was used. All panel tie-in seams (i.e., T-seams) were extrusion welded/repaired. During the repair or panel tie-in operations, the following provisions were implemented:

- technicians and seaming equipment used during repair operations had trial seams approved prior to use;
- geomembrane surfaces to be repaired were clean and dry at the time they were welded;
- patches or caps extended at least 6 in. (0.15 m) beyond the edge of the defect, and all corners were rounded;
- fusion annuli were ground down to the surface of the bottom geomembrane at the ends of the seams; and
- repairs were vacuum tested where accessible, and visually observed for continuity.

Appendix O presents repair summary logs for the secondary liner geomembrane and the primary liner geomembrane. Seam and panel repair locations are presented in Appendix P. Complete panel layout drawings indicating the location of seam and panel repairs are shown on the Record Drawings presented in Appendix S.

5.4.6 Electrical Leak Detection Testing

The electrical leak detection testing was performed on selected portions of the Cell 3 primary liner geomembrane. The method uses the flow of electrical current to detect leaks or breaches in a geomembrane liner. The testing was performed as a demonstration program to evaluate the feasibility and effectiveness of using the electrical leak location method as supplemental CQC/CQA monitoring of future installation of the geomembrane components of the OSDF liner and cap systems. The testing was performed in the drainage corridor area and impacted runoff catchment area of the Cell 3 primary liner geomembrane. The drainage corridor and catchment area were identified as critical areas because they are the lowest points within the Cell 3 footprint, and as such, have the potential for leachate head to build-up on the primary liner. Any leaks through the primary liner due to defects in the geomembrane are more likely to occur in these areas than other areas within the Cell 3 footprint. The leak detection testing was performed by Solmers International (Solmers) of Lonqueuil, Canada as subcontractor to GeoSyntec. No leaks were detected in the primary liner geomembrane in the selected portions that were tested. Appendix Q presents a draft report on the electric leak detection testing which was conducted as part of the OSDF Cell 3 lining system construction.

5.5 CQA of Geotextile

5.5.1 Conformance Testing and Documentation

Three types of geotextile were used in construction of Cell 3:

- a needlepunched nonwoven geotextile having a minimum mass per unit area of 7 oz/yd^2 (240 g/m^2) was used for as the geotextile filter layer. This geotextile was manufactured by TNS Advanced Technologies, Inc., Lilburn, Georgia;

- a needlepunched nonwoven geotextile having a minimum mass per unit area of 10 oz/yd^2 (340 g/m^2) was used as the geotextile cushion layer. This geotextile was manufactured by TNS Advanced Technologies, Inc., Lilburn, Georgia; and

- a needle punched nonwoven geotextile having a minimum mass per unit area of 16 oz/yd^2 (540 g/m^2) was used as the supplemental geotextile cushion layer. This geotextile was manufactured by TNS Advanced Technologies, Inc., Lilburn, Georgia.

CQA personnel obtained 16 conformance samples from the 285 geotextile rolls delivered to the site. Six (6) conformance samples were obtained from 68 rolls of geotextile filter, 9 conformance samples were obtained from 120 rolls of geotextile cushion, and 1 conformance sample was obtained from 11 rolls of supplemental geotextile cushion. These sampling frequencies exceed the minimum acceptable frequency of one per 100,000 ft^2 (9,300 m^2) required by the project documents. The conformance samples were forwarded to GeoTesting Express, Inc. for testing. The conformance test results and the manufacturer's QC certificates were reviewed by CQA personnel and were found to be in compliance with the project documents. The manufacturer's QC documentation is presented in Appendix H. The conformance test results are presented in Appendix I. A summary of the properties of the geotextile material and the conformance test results for the geotextile filter, geotextile cushion and supplemental geotextile cushion is presented in Tables 5-5, 5-6 and 5-7, respectively.

5.5.2 Field Monitoring Activities

5.5.2.1 Delivery and On-Site Storage

Upon delivery to the site, geotextile rolls were stored in an area located southeast of future Cell 4 construction area. The geotextile rolls had a plastic wrapping to protect against ultraviolet radiation, dust, and dirt. The geotextile rolls were transported by a front-end loader. The rolls were deployed or temporarily stored adjacent to the construction area prior to deployment. CQA personnel periodically monitored the delivery, unloading, and storage procedures. The CQA personnel observed that the material was handled in an appropriate manner.

5.5.2.2 Deployment

CQA personnel monitored the deployment of the geotextile rolls for the following:

- manufacturing defects;
- damage that may have occurred during shipment, storage, and handling; and
- damage resulting from installation activities.

If any materials were observed to be damaged, the installer was notified and the damaged materials were either discarded or repaired. CQA personnel observed repair locations, either during or after the repair was complete.

CQA personnel monitored the deployment of the geotextile as well as its condition after installation, to ensure that the installer:

- unrolled the geotextile down the slope in a manner which kept the geotextile panel in sufficient tension to avoid excessive wrinkling and folding; and
- took measures to avoid the entrapment of dust, stones, and other objects in the geotextile.

After deployment of the geotextile, CQA personnel observed that the following procedures were used by the installer to join adjacent rolls of geotextile:

- geotextile panels were overlapped a minimum of 6 in. (0.15 m); and
- geotextile panels were continuously sewn.

The installer used a 2200-B Union Special sewing machine. The seams were sewn with a single-thread chain stitch using a nylon bonded thread.

The installer repaired holes or tears in the geotextile by placing a patch of the same material over the hole or tear with at least 2 ft (0.6 m) beyond the edges of the hole or tear and thermally bonded with a leister or overlapped 6 in. (150 mm) and sewn.

5.6 CQA of Liner Penetration Boxes

Cell 3 liner penetration boxes were fabricated by Plastek Werks, Inc., Gainesville, Georgia. GeoSyntec reviewed shop drawings and fabrication procedures prior to production. Liner penetration boxes were air pressure tested in the factory and in the field, as required, filled with bentonite, and sealed. The manufacturer's QC documentation on the fabrication of the liner penetration boxes is presented in Appendix H. Pressure test logs for the liner penetration boxes are presented in Appendix R. Geomembrane connections to the liner penetration boxes were nondestructively tested using the vacuum-box testing procedures outlined in Section 5.4.3.3. CQA personnel monitored the installation and testing activities for the liner penetration boxes.

5.7 CQA of HDPE Piping

CQA personnel monitored the installation of the various HDPE piping components of the LDS and LCS. Installation activities that were monitored by GeoSyntec's CQA personnel included the following:

- 6-in. (150-mm) nominal diameter HDPE SDR-11 perforated pipes located within the LDS and LCS drainage corridors;

- LDS gravity pipeline, consisting of a 6-in. (150-mm) nominal diameter HDPE SDR-11 solid-wall carrier pipe inside a 10-in. (250-mm) nominal diameter HDPE SDR-11 solid-wall containment pipe, which transitions within an LDS manhole to a 3-in. (75-mm) nominal diameter HDPE SDR-11 solid-wall carrier pipe inside a 8-in. (200-mm) nominal diameter HDPE SDR-11 solid-wall containment pipe and ultimately connects within manhole MH-3 to a main leachate conveyance system pipe;

- redundant LCS gravity pipeline, consisting of a 6-in. (150 mm) nominal diameter HDPE SDR-11 solid-wall carrier pipe inside a 10-in. (250-mm) nominal diameter HDPE SDR-11 solid-wall containment pipe, and ultimately connects within manhole MH-3 to a main leachate conveyance system pipe; and

- LCS gravity pipeline, consisting of a 6-in. (150-mm) nominal diameter HDPE SDR-11 solid-wall carrier pipe inside a 10-in. (250-mm) nominal diameter HDPE SDR-11 solid-wall containment pipe, and ultimately connects within manhole MH-3 to a main leachate conveyance system pipe.

5.7.1 Pipe Conformance Testing and Documentation

The LCS and LDS pipes were delivered to the site during Cell 3 construction. Phillips Driscopipe of Hagerstown, Maryland supplied the pipe. The pipe manufacturer provided the QC certifications for each lot of pipe supplied. The manufacturer's QC certificates are included in Appendix H. CQA personnel reviewed this documentation and verified that the pipe property data were in compliance with the requirements of the project documents. CQA personnel also verified the proper size and spacing of the perforations by visual observation of the pipe while stored or during installation. No conformance testing of the pipe was required by the CQA Plan.

5.7.2 Field Monitoring Activities

The pipe was shipped from the manufacturer on wooden pallets. Upon delivery to the site, pipe was stored in an area located in a laydown area northwest of Cell 1. The pipe was transported from the storage area to the construction area by a trackhoe or a front-end loader using nylon straps. The pipe was deployed or temporarily stored adjacent to the construction area.

The 40-ft (12-m) long sections of pipe were joined using butt-fusion welding techniques. The CQA activities associated with each of the pipe joining techniques are described below.

CQA personnel monitored the HDPE pipe butt-fusion welding procedures to ensure the following:

- the ends of the pipes to be joined were cleaned and the pipe sections were aligned;
- the welder tightly secured the pipe section in the welding unit clamps to allow the ends of the pipes to be trimmed with the facing tool immediately prior to the application of the heat disk;
- the ends of the pipe sections were heated for approximately one minute using a 375 to 500°F (191 to 260°C) heating disk;
- the welder quickly removed the heating disk and joined the pipes with pressures recommended by the fusion machine manufacturer; and
- after the butt-fusion weld was allowed to cool, the joined pipes were released from the welding unit.

Within the Cell 3 area, the perforated piping system was constructed to allow drainage toward the liner penetration boxes, located at the west end of the cell. The LDS and LCS pipes were installed with perforations along the lengths of the pipes. Each pipe had 3 rows of 5/8 in. (16 mm) diameter holes on 6 in. (150 mm) centers along the length. Each row was staggered 2 in. (50 mm). LDS and LCS drainage corridor material (i.e., No. 57 stone) was placed around the pipe. Both the pipe and aggregate were installed over a 16-oz/yd^2 (540-g/m^2) needlepunched nonwoven supplemental geotextile cushion layer.

The following approximate lengths of pipe were installed in the Cell 3 area:

- 660 ft (201 m) of 6-in (150-mm) nominal diameter HDPE SDR-11 LDS perforated pipe;
- 660 ft (201 m) of 6-in (150-mm) nominal diameter HDPE SDR-11 LCS perforated pipe; and

- 230 ft (70 m) of 6-in. (150-mm) nominal diameter HDPE SDR-11 LCS redundant perforated pipe.

The HDPE piping within Cell 3 was connected to the liner penetration boxes described in Section 5.6. The perforated sections of the LDS pipe was connected to the solid-wall section of the pipe from the liner penetration box using the butt-fusion welding procedures described above. The perforated sections of the LCS and redundant LCS pipes were connected to the solid-wall sections of the pipes from the liner penetration boxes using electrofusion couplings. CQA personnel monitored the electrofusion welding procedures to ensure the following:

- the ends of the pipes were cut square and even;

- the ends of the pipes to be joined were cleaned and surface prepared inside and out;

- the leads from the electrofusion coupling were secured to the processing unit supplied by the manufacturer;

- the processing unit was activated to produce a voltage range across the electrofusion coupling which induced melting; and then performed a unit test to evaluate the coupled joint; and

- the electrofusion weld was allowed to cool in accordance with manufacturer's recommendations.

The liner penetration boxes were the only points of penetration through the geomembrane liners. Leachate will be discharged through the liner penetration boxes within Cell 3 via gravity pipeline to the leachate conveyance system. The leachate conveyance system is comprised of an LDS and LCS manhole and transmission pipe that conveys leachate to the permanent lift station (PLS). The PLS pumps leachate via a forcemain within a containment pipe to the BioSurge Lagoon. Enhancement to the leachate conveyance system from manhole MH-3 to Cell 3 is described in Section 6.

TABLE 5-3

80-MIL THICK HDPE GEOMEMBRANE (TEXTURED) PROPERTIES SUMMARY
CELL 3

DESCRIPTION	TEST STANDARD	MANUFACTURER[3] SPECIFICATIONS (MARV)[7]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (ft^2)		NUMBER OF TESTS[2]				RANGE OF QA TEST RESULTS	
						REQUIRED		PASSING			
				Manf. QC	Conf. QA[4]	Manf. QC	Conf. QA	Manf. QC	Conf. QA	MAXIMUM	MINIMUM
Yield Strength (lb/in.)	ASTM D 638[5]	173	≥168 [6]	40,000	100,000	21	9	83	9	231	200
Elongation at Yield (%)	ASTM D 638[5]	13	≥12	40,000	100,000	21	9	83	9	28	15
Break Strength (lb/in.)	ASTM D 638[5]	324	≥120 [6]	40,000	100,000	21	9	83	9	476	345
Elongation at Break (%)	ASTM D 638[5]	560	≥100	40,000	100,000	21	9	83	9	1001	707
Thickness (mil)	ASTM D 5994	80 nominal 76 min.	Avg. 80 Min. 76	40,000	100,000	21	9	83	9	83	82
Specific Gravity (NA)	ASTM D 792 or ASTM D 1505	0.940	≥0.935 (resin) ≥0.940 (sheet)	40,000[4]	100,000	21	9	83	9	0.948	0.945
Tear Resistance (lb)	ASTM D 1004 Die C Puncture	60	≥56	40,000	NA	21	NA	83	NA	NA	NA
Carbon Black Content (%)	ASTM D 1603	2.0	2-3	40,000	100,000	21	9	83	9	2.7	2.3
Carbon Black Dispersion	ASTM D 5596	Category 1 or 2	Category 1 or 2	40,000	100,000	21	9	83	9	CAT. 1	CAT. 2
Low Temperature Brittleness (°C)	ASTM D 746B	-75	-60 max.	400,000	NA	3	NA	3	NA	NA	NA
Dimensional Stability (%) (@ 212°F, 1 min.)	ASTM D 1204	±2 max.	±2 max.	400,000	NA	3	NA	83	NA	NA	NA
ESCR (hr)[6]	ASTM D 5397	500	≥500	400,000	NA	3	NA	3	NA	NA	NA

Total Number of Rolls Delivered to Site: 83 (760,695 ft^2)

Total Number of Conformance Samples: 9

Notes:
(1) Reference Section 02770P of the Specifications and Section 7 of the CQA Plan for further details.
(2) The approximate number of tests required is based on total of 760,695 ft^2 for the Cell 3 installation.
(3) GSE Lining Technologies, Houston, Texas is the geomembrane supplier. Roll dimensions are 23.5 ft. x 390 ft. (avg. Length)
(4) Tests performed at a frequency of one per lot or at listed frequency, whichever is greater. A lot is as defined by ASTM 4354. Minimum test frequency of resin is 1 test per railcar.
(5) ASTM D 638 is modified by NSF-54 Annex A.
(6) Time-to-failure at a tensile stress of 30% of the tensile yield strength
(7) MARV = (minimum average roll value), 95 percent lower confidence limit.

TABLE 5-4

80-Mil Thick HDPE GEOMEMBRANE (PRIMARY/SECONDARY) (TEXTURED) SEAM PROPERTIES SUMMARY CELL 3

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS		REQUIREMENTS	APPROXIMATE NUMBER OF TESTS REQUIRED
		Fusion	Extrusion		
Panel Deployment	-	-	-	Ambient placement temperature are between 40° and 104°F.	Assumption used for destructive seam testing is that eac roll is approximately 24 ft by 357 ft (avg.)
Trial Seams: (peel)	ASTM D 4437	FTB 115 ppi	FTB 84 ppi	Prior to seaming period every 5 hours, or if seaming apparatus is turned off.	Minimum of: 2 no. peel per trial seam 2 no. shear per trial seam
(shear)	ASTM D 4437	FTB 151 ppi	FTB 151 ppi		

Notes: (1) One failure requires two consecutive successful trial seams.

DESCRIPTION	TEST STANDARD	PROJECT[1][2][3] SPECS		TEST FREQUENCY	APPROXIMATE NUMBER OF TESTS REQUIRED	ORIGINAL NO. OF SAMPLES	NUMBER OF FAILURES		ADDITIONAL NUMBER OF SAMPLES TO ISOLATE FAILURES	TOTAL NUMBER OF SAMPLES
		Fusion	Extrusion				FIELD	LAB		
Seam Strength[1]: Production Welds and Reconstructed Seams	ASTM D 4437	FTB 115 ppi	FTB 84 ppi	500 lin. ft	secondary min. of 32	secondary min. of 33	secondary 3	secondary 0	secondary 7	secondary 40
	ASTM D 4437	FTB 151 ppi	FTB 151 ppi		primary min. of 32	primary min. of 34	primary 5	primary 5	primary 17	primary 51

Note: (1) Reference Section 02770P of the Specifications and Section 7 of the CQA Plan for further details.
(2) 1 in. wide test strips are tested at a strain rate of 2 in. per minute. One non-FTB per five specimens is acceptable provided that the strength requirements are met.
(3) FTB = Film Tear Bond (maximum 10 percent seam separation)

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TABLE 5-5

NONWOVEN GEOTEXTILE (7 oz/yd^2) FILTER PROPERTIES SUMMARY
CELL 3

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2]				RANGE OF QA TEST RESULTS	
						REQUIRED		PASSING			
				Manf. QC	Conf. QA	Manf. QC	Conf. QA	Manf. QC	Conf. QA	MAXIMUM	MINIMUM
Mass Per Unit Area (oz/yd^2)	ASTM D 5261	7	≥7	50,000	100,000	9	5	9	6	9.0	8.0
Mullen Burst Strength (psi)	ASTM D 3786	400	≥350	50,000	100,000	9	5	9	6	496	431
Grab Strength (lb)	ASTM D 4632	200	≥180	50,000	100,000	9	5	9	6	305	250
Trapezoidal Tear Strength Tear (lb)	ASTM D 4533	85	≥75	50,000	100,000	9	5	9	6	166	105
Puncture Strength Resistance (lb)	ASTM D 4833	130	≥75	50,000	100,000	9	5	9	6	164	144
Apparent Opening Size (mm) (A.O.S.)	ASTM D 4751	0.180	≤0.212	100,000	100,000	5	5	9	6	0.15	0.13
Permittivity (sec^{-1})	ASTM D 4491	1.50	≥0.5	100,000	100,000	5	5	9	6	2.16	1.65
Ultraviolet Resistance (%)	ASTM D 4355	70	≥70	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA
Nonwoven Needle punched Polymer Composition (%)	—	95% polypropylene	95 polypropylene or polyester by weight	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA

Total Number of Rolls Delivered to Site: 68

Total Number of Conformance Samples: 6

Notes:
(1) Reference Section 02714P of the Specifications and Section 9 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total of 459,000 ft^2 available for the Cell 3 installation.
(3) Roll dimensions are 15 ft by 450 ft for 7-oz/yd^3 geotextile manufactured by TNS Advanced Technologies, Inc., Lilburn, Georgia.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

TABLE 5-6

NONWOVEN GEOTEXTILE (10 oz/yd²) CUSHION PROPERTIES SUMMARY
CELL 3

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2] REQUIRED		NUMBER OF TESTS[2] PASSING		RANGE OF TEST RESULTS	
				Manf. QC	Conf. QA	Manf. QC	Conf. QA	Manf. QC	Conf. QA	MAXIMUM	MINIMUM
Mass Per Unit Area (oz/yd²)	ASTM D 5261	10	≥10	50,000	100,000	16	8	16	9	11.2	10.2
Mullen Burst Strength (psi)	ASTM D 3786	510	≥450	50,000	100,000	16	8	16	9	617	531
Grab Strength (lb)	ASTM D 4632	250	≥225	50,000	100,000	16	8	16	9	420	288
Trapezoidal Tear Strength Tear (lb)	ASTM D 4833	100	≥90	50,000	100,000	16	8	16	9	200	126
Puncture Strength Resistance (lb)	ASTM D 4833	160	≥120	50,000	100,000	16	8	16	9	204	178
Ultraviolet Resistance (%)	ASTM D 4355	70	≥70	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA
Nonwoven Needle punched Polymer Composition (%)	—	90% polypropylene	95 polypropylene or polyester by weight	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA

Total Number of Rolls Delivered to Site: 120

Total Number of Conformance Samples: 9

Notes:
(1) Reference Section 02714P of the Specifications and Section 9 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total of 810,000 ft² available for the Cell 3 installation.
(3) Roll dimensions are 15 ft by 450 ft for 10-oz/yd³ geotextile manufactured by TNS Advanced Technologies, Inc., Lilburn, Georgia.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

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2680

TABLE 5-7

NONWOVEN GEOTEXTILE (16 oz/yd^2) SUPPLEMENTAL CUSHION PROPERTIES SUMMARY
CELL 3

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2] REQUIRED		NUMBER OF TESTS[2] PASSING		RANGE OF TEST RESULTS	
				Manf. QC	Conf. QA	Manf. QC	Conf. QA	Manf. QC	Conf. QA	MAXIMUM	MINIMUM
Mass Per Unit Area (oz/yd^2)	ASTM D 5261	16	≥16	50,000	100,000	2	1	2	1	16.9	16.9
Mullen Burst Strength (psi)	ASTM D 3786	800	≥700	50,000	100,000	2	1	2	1	918	918
Grab Strength (lb)	ASTM D 4632	380	≥350	50,000	100,000	2	1	2	1	660	455
Trapezoidal Tear Strength Tear (lb)	ASTM D 4533	145	≥120	50,000	100,000	2	1	2	1	306	189
Puncture Strength Resistance (lb)	ASTM D 4833	240	≥180	50,000	100,000	2	1	2	1	303	303
Ultraviolet Resistance (%)	ASTM D 4355	70	≥70	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA
Nonwoven Needle punched Polymer Composition (%)	NA	95% polypropylene	95 polypropylene or polyester by weight	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA

Total Number of Rolls Delivered to Site: 11

Total Number of Conformance Samples: 1

Notes: (1) Reference Section 02714P of the Specifications and Section 9 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total of 74,250 ft^2 available for the Cell 3 installation.
(3) Roll dimensions are 15 ft by 450 ft for 16-oz/yd^3 geotextile manufactured by TNS Advanced Technologies, Inc., Lilburn, Georgia.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

6. CONSTRUCTION QUALITY ASSURANCE – ENHANCEMENT TO LEACHATE CONVEYANCE SYSTEM

6.1 General

GeoSyntec monitored the enhancement to the leachate conveyance system between manhole MH-3 and Cell 3. The enhancement includes: (i) replacement of approximately 30-ft (9-m) long section of the existing, HDPE SDR-26 dual-containment piping system, immediately east of manhole MH-3, with a new HDPE SDR-11 dual-containment piping system; and (ii) replacement of existing electrofusion couplings on the dual-containment pipes with thermal butt-fusion joints and extrusion-welded sleeves. The enhancement to the leachate conveyance system was performed based on the lessons learned from the leak investigation studies on the leachate transmission system [FDF, 1999; GeoSyntec, 1999a]. The installation of the above components of the leachate conveyance system between manhole MH-3 and Cell 3 was performed by FDF Construction with assistance from Wise and Lee Supply. Construction activities that were monitored by GeoSyntec CQA personnel included the following:

- excavation of the compacted fill and embedment fill around the manholes, cleanouts and pipes to expose the dual-containment pipes and joints;
- replacement of approximately 30-ft (9-m) long HDPE SDR-11 dual-containment piping systems for the LDS, LCS and LCS-redundant lines from manhole MH-3 to Cell 3 using thermal butt-fusion joints and extrusion welded sleeves;
- hydrostatic and pneumatic pressure testing of the dual-containment piping systems between manhole MH-3 and Cell 3 after the repairs/replacement;
- trench backfilling with embedment fill and compacted fill; and
- installation of temporary covers around the manholes and cleanouts; and

- final grading of the manhole MH-3 area.

6.2 Changes in Drawings and Specifications

DCN Nos. 1700-095 and 1700-096 were processed and approved according to procedures described in FEMP document ED-12-5002 entitled "Engineering Design Change Process." Copies of these DCNs are presented in Appendix T. These were used as the basis to conduct the enhancement to the leachate conveyance system between manhole MH-3 and Cell 3.

6.3 Pipe Conformance Testing and Documentation

The pipes for the enhancement work were manufactured by Phillips Driscopipe of Hagerstown, Maryland, and supplied by Lee Supply. The manufacturer provided the QC certifications for each lot of pipe supplied. The manufacture's QC certificates are presented in Appendix H. CQA personnel reviewed this documentation and verified that the pipe was in compliance with the requirements of the project documents.

6.4 Field Monitoring Activities

6.4.1 Delivery and Placement

Upon delivery to the site, the pipes were placed in laydown areas approved by FDF. The pipes were transported from the laydown area to the construction area by a trackhoe or a forklift using nylon straps.

The replacement pipeline was joined to the existing line using butt-fusion and/or extrusion welded-sleeves welding techniques. The procedures used in joining the pipes were in accordance with the recommendations and procedures presented in the leachate transmission system (LTS) evaluation report [GeoSyntec, 1999a]. The CQA activities associated with each of the pipe joining and/or repair techniques are described below.

CQA personnel periodically monitored the HDPE pipe butt-fusion welding procedures to ensure the following:

- trial butt fusion joints were made to verify conditions were adequate at the beginning of each day for each fusion apparatus used that day (trial joining was made under the same conditions as the actual joining);
- the ends of the pipes to be joined were cleaned and the pipe sections were placed in a portable welding unit;
- the welder tightly secured the pipe section in the welding unit clamps to allow the ends of the pipes to be trimmed with the facing tool immediately prior to the application of the heat disk;
- the ends of the pipe sections were heated for approximately one minute using a 375 to 500°F (191 to 260°C) heating disk;
- the welder quickly removed the heating disk and joined the pipes with pressures recommended by the fusion machine manufacturer;
- the butt-fusion weld was allowed to cool prior to the joined pipes being released from the welding unit; and
- all of the above performed in general accordance with pipe and welding unit manufacturer's procedures.

CQA personnel monitored the extrusion welding of the containment pipe sleeves to ensure that:

- the ends of the pipes were free and sufficient space beneath the pipe had been excavated;
- the sleeve was of sufficient length to allow for a 6 in. (150 mm) overlap;
- the ends of the sleeves were cut square and a 45-degree bevel was cut around the circumference of the inside edge of the sleeve;

- the inside and outside surfaces of the containment pipe and sleeve were cleaned and the surfaces to be welded were properly ground and cleaned again to remove any grit or cutting;

- the sleeve and both containment pipes were centered and aligned vertically and horizontally;

- trial welds were made on sections of scrap pipe to verify conditions were adequate for conducting the production welds;

- moisture was removed from the surfaces to be welded using hot air at temperature greater than 120°F (49 °C);

- extrusion welding was performed along the notched annular space formed by the bevel edge of the sleeve and the containment pipe, and multiple passes were applied around the circumference to establish a good weld; and

- the joint was allowed to cool down for at least 30 minutes before backfilling or performing any other activities that could cause movement of the pipe.

6.4.2 Testing Activities

As part of the CQA activities, tests were performed on the enhancement to the leachate conveyance system between manhole MH-3 and Cell 3. The following tests were conducted or monitored by CQA personnel for the compacted fill, embedment fill, or piping systems:

- Particle-size distribution tests were performed on samples of compacted fill, embedment fill and granular filter materials according to ASTM D 422 or ASTM C 136.

- In-place nuclear moisture/density tests were conducted on the compacted fill used in backfilling the pipe trenches and around the manholes and cleanouts.

- Preliminary and final pressure tests were conducted by the contractor on the carrier and containment pipes of the dual-containment piping system between manhole MH-3 and Cell 3. These tests were monitored by GeoSyntec's CQA personnel.

CQA personnel obtained representative samples of embedment fill material and performed particle-size distribution tests. The materials are classified as SP based on the USCS. The geotechnical laboratory test results are presented in Appendix G.

CQA personnel conducted nuclear moisture/density tests on the compacted fill within the leachate conveyance system gravity trenches and around the manholes and cleanouts. All met the minimum degree of compaction of 95 percent of the maximum dry unit weight, as determined by the standard Proctor compaction test. The nuclear moisture/density test results are given in Appendix G.

CQA personnel monitored placement and compaction of embedment fill material. Material was compacted using four passes of vibratory plate compactor.

CQA personnel also monitored the pressure testing performed by Wise and Lee Supply. A 5-psi (34.5 kPa) pneumatic test was initially performed as a preliminary test to check each joint. Final hydrostatic tests were then performed after the work was completed. For these tests, the contractor tested the pipes with water to a minimum of 120 psi (828 kPa) for the carrier pipe and 15 psi (103 kPa) for the containment pipe. The pressure was monitored by CQA personnel for a minimum period of 3 hours during which time the pressure in the pipe was recorded. An allowance for expansion/contraction of the pipe during hydrostatic testing was included in the pass/fail criterion for the pressure test. The final pressure tests were performed in accordance with DCN No. 20102-092.

The pressure test results and CQA documentation from the enhancement to the leachate conveyance system between manhole MH-3 and Cell 3 are presented in Appendix R.

7. SUMMARY AND CONCLUSIONS

Construction of the OSDF Phase II Cell 3 project for the FEMP was carried out during the period from late March 1999 to 05 November 1999. During this time, GeoSyntec provided on-site CQA personnel to monitor the construction of the OSDF Cell 3 lining system and enhancement to the leachate conveyance system between manhole MH-3 and Cell 3. As part of the CQA activities, GeoSyntec on-site CQA personnel monitored the construction and installation of the following components:

- earthwork (subgrade preparation, perimeter and intercell berm construction, compacted clay liner/clay wedge construction, LDS and LCS drainage layer construction, and protective layer placement);

- geosynthetics (installation of GCL, primary liner and secondary liner geomembranes, and geotextile layers for the Cell 3 lining system); and

- leachate conveyance system construction and enhancement (installation of LDS and LCS collection pipes, and liner penetration boxes, and replacement to the LDS, LCS and LCS redundant solid-wall gravity pipes from Cell 3 to manhole MH-3).

During construction of the above components, CQA personnel verified that conformance and CQA testing were performed on the construction materials at the frequencies required by the project documents, and that materials meeting the project document requirements were used. CQA personnel also verified that conditions or materials identified as not conforming to the project documents were replaced, repaired, and/or retested, or that clarifications to the project documents were approved by the Resident Engineer to allow the conditions or materials to be used, as described in this report. All non-conformances associated with the construction were resolved through disposition by the Construction Manager with concurrence by the FDF Engineering/QA and Resident Engineer. Copies of the non-conformance reports (NCRs) that were written during the Phase II Cell 3 construction project are included as Appendix V to this CQA final report.

The results of the CQA activities undertaken by GeoSyntec as described in this report indicate that the Phase II Cell 3 lining system and enhancement to the leachate conveyance system for the OSDF were constructed in accordance with the Technical Specifications, Construction Drawings, CQA Plan, and all applicable DCNs.

14 Dec '99

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