4938

CONSTRUCTION QUALITY ASSURANCE

FINAL REPORT

PHASE IV - CELLS 4 AND 5 CONSTRUCTION ON-SITE DISPOSAL FACILITY

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by

GEOSYNTEC CONSULTANTS

Fernald Field Office
7400 Willey Road, MS:38
Hamilton, Ohio 45013

under

Fluor Fernald, Inc.
Contract No. 95PS005028

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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CONSTRUCTION QUALITY ASSURANCE FINAL REPORT PHASE IV - CELLS 4 AND 5 CONSTRUCTION ON-SITE DISPOSAL FACILITY

June 2003
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GeoSyntec Consultants
Fluor Fernald

ACRONYMS AND ABBREVIATIONS

APZ	Acceptable Permeability Zone
ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society of Testing and Materials
CCT	Closed-Circuit Television
CETCO	Colloid Environmental Technologies Company
CFC	Certified-For-Construction
CM	Construction Manager
CQA	Construction Quality Assurance
CQC	Construction Quality Control
CVH	Control Valve House
DCN	Design Change Notice
DCP	Design Criteria Package
DOE	Department of Energy
EFBA	East Field Borrow Area
EPLTS	Enhanced Permanent Leachate Transmission System
FEMP	Fernald Environmental Management Project
FFC	Fluor Fernald Construction
GCL	Geosynthetic Clay Liner
GIS	Gravity Inlet Structure
HDPE	High Density Polyethylene
HMW	Horizontal Monitoring Well
IMP	Impacted Material Placement
LCS	Leachate Collection System
LDS	Leak Detection System
LGP	Low Ground Pressure
LLRW	Low-Level Radioactive Waste
LLSI	Leak Location Services, Inc.

ACRONYMS AND ABBREVIATIONS

LTS	Leachate Transmission System
MDD	Maximum Dry Density
MH	Manhole
NCR	Nonconformance Repor
OAC	Ohio Administrative Code
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
OMC	Optimum Moisture Content
OSDF	On-Site Disposal Facility
PLS	Permanent Lift Station
QA	Quality Assurance
QC	Quality Control
RCI	Request for Clarification of Information
RCRA	Resource Conservation and Recovery Act
RLCS	Redundant Leachate Collection System
SDFP	Soil and Disposal Facility Project
SWMEC	Surface Water Management and Erosion Control
SWP	Soil and Water Project
TIC	The Istre Company
TPPFR	Test Pad Program Final Report
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VH	Valve House
WAC	Waste Acceptance Criteria
WAO	Waste Acceptance Organization

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 On-Site Disposal Facility (OSDF) Phase IV – Cells 4 and 5 construction 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, testing and documentation of the construction of the various components of the Cells 4 and 5 liner systems, and included: (i) earthwork construction, and (ii) geosynthetics installation. In addition, GeoSyntec performed the appropriate and relevant CQA activities during the: (i) excavation and screening of clay liner and cap material in the East Field Borrow Area (EFBA) for future Cell 6 liner and Cell 2 final cover construction; (ii) tie-in of the dual-containment pipes from valve house (VH) No. 4 and No. 5 to Cells 4 and 5 outlets, respectively; (iii) construction of horizontal monitoring well (HMW) for future Cell 6; (iv) extensions of the dual-containment pipes from the valve house (VH) No. 6 stub-outs to future Cell 6 outlet; and (v) excavation and construction of OSDF Sedimentation Basin No. 2. 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 (CFC) drawings, technical specifications, CQA plan, and approved design and/or specification changes.

This report was prepared for Fluor Fernald, Inc. under Subcontract 95PS005028 by Dr. Kwasi Badu-Tweneboah, P.E., Mr. Collin P. Sukow and Mr. T. Byran York, E.I.T, all of GeoSyntec.

1.2 Background

The OSDF is a mixed low-level radioactive waste (LLRW) disposal facility dedicated to the FEMP that, upon completion, will cover approximately 90 acres (36 hectares). The OSDF is owned by the Department of Energy (DOE) and is being constructed, operated for waste disposal, and closed under the management of Fluor Fernald, Inc. as part of the overall FEMP remediation activities.

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. The OSDF is being developed in several phases. Construction of the liner systems, placement of impacted material, and construction of the final cover system for the OSDF cells are scheduled to be completed by December 2006 [Fluor Fernald, 2002].

The first year (1997) of construction included the OSDF Phase I liner system for Cell 1 and the overall Leachate Management System projects. The Leachate Management System projects consisted of: (i) the OSDF leachate transmission system (LTS) component that included manholes MH-1, MH-2, and MH-3, respectively, for Cells 1 through 3, and a dual-containment high density polyethylene (HDPE) gravity piping system from manhole MH-1 to the permanent lift station (PLS); and (ii) the Leachate Conveyance System that consisted of a force main from the PLS to the biosurge lagoon. The interface between OSDF Phase I and the overall Leachate Management System was at the stub-outs of the manholes for Cell 1 leachate collection and leak detection systems. Construction of the OSDF Phase I liner system for Cell 1, the OSDF LTS and the Leachate Conveyance System occurred between August and December 1997. A CQA Final Report for the OSDF Phase I - Cell 1 liner system and the overall Leachate Management System construction was prepared and issued by GeoSyntec in January 1998 [GeoSyntec, 1998a].

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

The third year (1999) of construction consisted of the Cell 3 liner system and placement of impacted material in Cells 1, 2, and 3 as part of the OSDF Phase II, Option 1 project. Construction of the Cell 3 liner system occurred between April and October 1999. A CQA Final Report for the OSDF Phase II - Cell 3 liner system construction was prepared and issued by GeoSyntec in November 1999 [GeoSyntec, 1999]. Placement of impacted materials in Cells 1 and 2 began in May 1999, while impacted materials placement in Cell 3 began in October 1999.

The fourth year (2000) of construction included placement of impacted materials in Cells 1, 2, and 3 as part of the OSDF Phase II, Option 2 project. Impacted materials placement began in March 2000 and was completed in September 2000 where Cell 1 was brought to final grades to facilitate construction of the final cover system. The fourth year of construction also included the Enhanced Permanent Leachate Transmission System (EPLTS) project that consisted of permanent LTS gravity line from Cell 1 to the permanent lift station (PLS); LTS valve houses (VHs) for each OSDF cell (a total of six); a control valve house (CVH) near the PLS; tie-in of the dual-containment pipes from Cells 1, 2, and 3 to the newly constructed VHs 1, 2, and 3, respectively; and the stub-outs from newly constructed VHs 4, 5, and 6, for future tie-in to dual-containment pipes from Cells 4, 5, and 6, respectively. A CQA Final Report for the EPLTS project was prepared and issued by GeoSyntec in October 2001 [GeoSyntec, 2001].

The fifth year (2001) of construction consisted of Cell 1 final cover construction and placement of impacted materials in Cells 2 and 3 as part of the OSDF Phase III project. Construction of the Cell 1 final cover system occurred between April and December 2001. A CQA Final Report for the OSDF Phase III – Cell 1 final cover construction was prepared and issued by GeoSyntec in September 2002 [GeoSyntec, 2002]. Placement of impacted materials in Cells 2 and 3 began in April 2001.

The Cells 4 and 5 liner systems were constructed as part of the OSDF Phase IV project in 2002 and is the primary subject of this report. This CQA Final Report presents a summary of the CQA monitoring, testing, and documentation activities performed by GeoSyntec during the OSDF Phase IV – Cells 4 and 5 construction project.

1.3 Report Organization

The remainder of this 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 general field documentation prepared by the CQA personnel is summarized in Section 4.

- A description of the CQA monitoring, testing, and documentation activities performed during the earthwork portion of the project is provided in Section 5.
- A description of the CQA monitoring, testing, and documentation activities performed during the geosynthetics installation is provided in Section 6.
- A description of the CQA monitoring, testing, and documentation activities that were performed during installation of the solid HDPE dual-containment piping systems is provided in Section 7.
- A summary of the observations resulting from the CQA monitoring, testing, and documentation activities performed by GeoSyntec; and a certification statement verifying that the OSDF Phase IV – Cells 4 and 5 liner systems project was constructed in general accordance with the project specifications, construction drawings, CQA plan, and approved design and/or specification changes are presented in Section 8.

2. PROJECT DESCRIPTION

The OSDF design incorporates a double-composite liner system, a final cover 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 [GeoSyntec, 2000]. The double-composite liner system, at the base of the OSDF, consists of the following components from top to bottom (Figure 2-1):

- 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 componet of the composite secondary liner; and
- varying thickness of prepared subgrade or compacted fill (hereafter referred to as subgrade).

Each of the Cell 4 and Cell 5 footprints has approximately 750-ft (230-m) long by 365-ft (110-m) wide rectangular configuration. Cell 4 is located immediately south of Cell 3 and is bounded by the Cell 3/Cell 4 intercell berm to the north and the Cell 4/Cell 5 intercell berm to the south. Cell 5 is located immediately south of Cell 4 and is

bounded by the Cell 5/Cell 6 intercell berm to the south. Cell 5 construction also includes a temporary termination to the liner system in the future Cell 6 footprint.

The Certified-For-Construction (CFC) Drawings and Technical Specifications for the OSDF Phase IV construction were prepared by GeoSyntec in accordance with the terms of Fluor Fernald Subcontract 95PS005028, GeoSyntec Project Number GQ1342. The prime contractor for construction of the OSDF Phase IV Cells 4 and 5 project was Fluor Fernald Construction (FFC) under the self-performance program for the closure of the FEMP [Fluor Fernald, 2002]. Installation of the geosynthetics components of the double-composite liner system for Cells 4 and 5 was performed by The Istre Company (TIC) of Glenpool, Oklahoma, as a subcontractor to FFC. Leak detection testing of the installed primary liner geomembrane was performed by Leak Location Services, Inc. (LLSI) of San Antonio, Texas, as subcontractor to FFC. The HDPE pipes for the Cells 4 and 5 liner systems and tie-in of the LDS, LCS, and RLCS dual-containment pipes to the Cells 4 and 5 outlets, Cell 6 HMW, and extensions of the dual-containment piping system from the VH-6 stub-outs to Cell 6 outlet were installed by Wise Construction Company (Wise) of Cincinnati, Ohio as subcontractor to FFC. Closed-circuit television (CCT) surveys of the Cells 4 and 5 LDS, LCS, and RLCS carrier pipes from each valve house with each cell were constructed by Water Workes, Inc. of Dayton, Ohio, as subcontractor to FFC. The surveyor retained by Fluor Fernald for the OSDF Phase IV – Cells 4 and 5 construction project was David E. Estes Engineering, Inc. (Estes) of Cincinnati, Ohio. CQA monitoring, testing, and documentation were provided by GeoSyntec. Fluor Fernald Quality Assurance (QA) also conducted independent CQA monitoring of the construction activities. A list of primary personnel involved in the OSDF Phase IV Cells 4 and 5 construction project is included in Section 3.2 of this report.

As required by the project specifications, Estes surveyed the required layers of the liner 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 as well as geomembrane panel layouts of the liner systems for Cells 4 and 5.

Primary construction activities monitored by GeoSyntec's CQA personnel for the OSDF Phase IV Cells 4 and 5 project included the following:

- rough grading of the cell floors (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 protective clay liner (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.

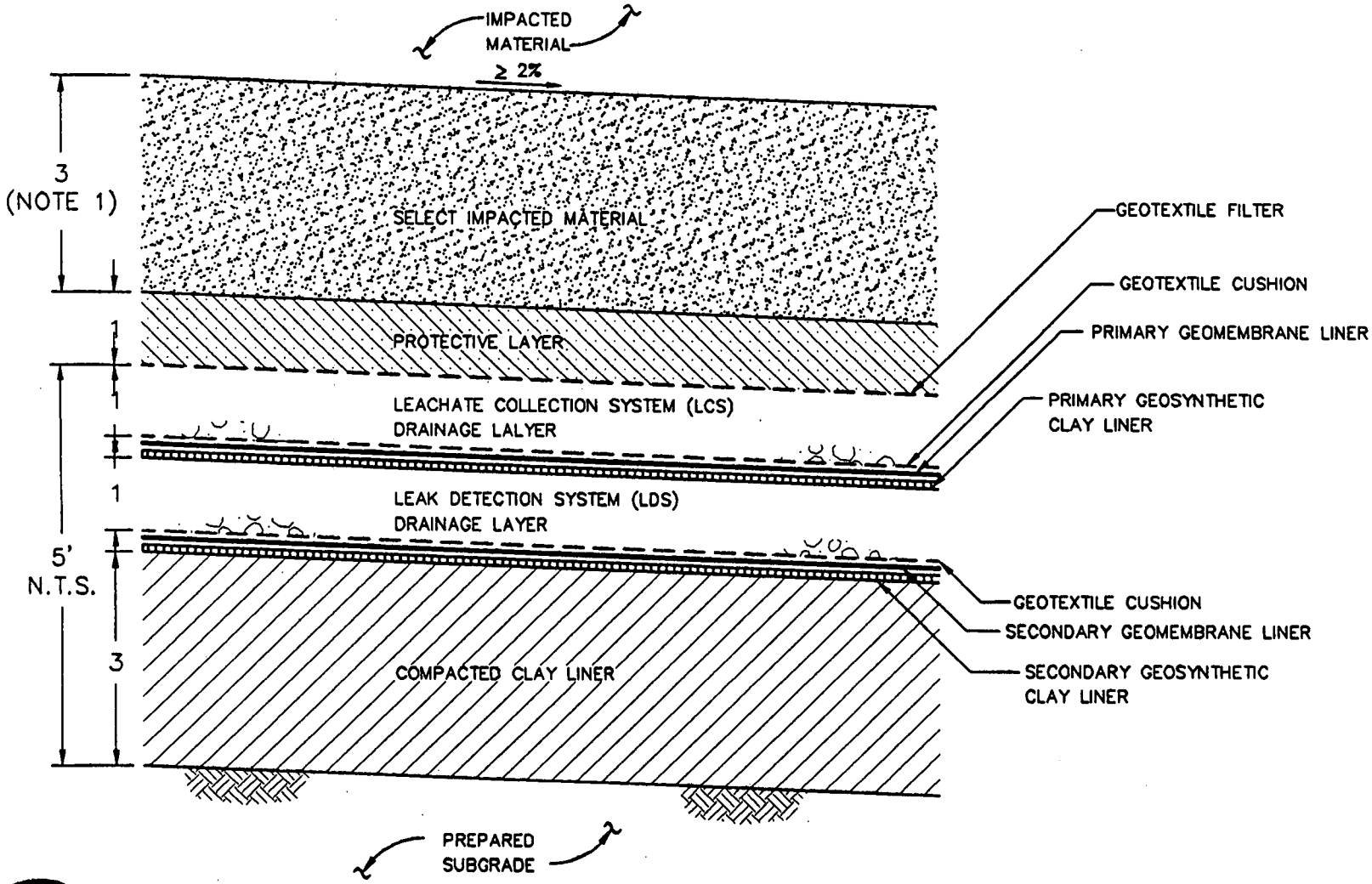
Construction activities monitored by GeoSyntec's CQA personnel for the piping systems for Cells 4 and 5 liner system, Cell 6 HMW, and tie-in and extensions of the dual-containment pipes included the following:

- trenching and excavation for the HDPE piping systems;
- placement and compaction of embedment fill for pipes;
- installation and welding of HDPE piping systems, including the Cell 6 HMW and tie-in of the dual-containment pipe extensions from the stub-outs at VH-6 to Cell 6 outlet;
- hydrostatic and/or pneumatic testing of the HDPE piping systems;
- CCT surveys and inspections of the LDS, LCS, and RLCS carrier pipes from VH-4 and VH-5 to Cells 4 and 5, respectively;
- installation of concrete pad cover slab, steel pipes, and ballasts over and around the HMW riser pipe and cleanout pipe; and
- backfilling and grading of the construction area.

The approval process for construction materials used during the OSDF Phase IV - Cells 4 and 5 project required Fluor Fernald to submit manufacturer's data, quality control certifications, supplier's certifications, and shop drawings to the Construction Manager (CM) for review and approval. Fluor Fernald was responsible for procurement of the geosynthetics. The Fluor Fernald CM, QA, 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, and are included in the appendices to this final report.

Earthwork associated with OSDF Phase IV Cells 4 and 5 construction began on 01 April 2003. TIC began and completed installation of the secondary liner geomembranes on 18 July 2002 and 13 September 2002, respectively. TIC began and completed installation of the primary liner geomembranes on 11 September 2002 and 5 November 2002, respectively. LLSI began and completed leak detection testing of the installed primary liner geomembranes on 25 September 2002 and 24 October 2002, respectively. The construction of the OSDF Phase IV Cells 4 and 5 liner systems was substantially completed on 19 November 2002, prior to beginning placement of protective layer material meeting the requirements of the Impacted Material Placement (IMP) Plan. Protective layer placement began on 08 November 2002 and was completed on 06 December 2002.

Earthwork associated with the installation of the HDPE piping system for Cell 6 began on 23 December 2002 and was substantively completed on 14 March 2003. Welding, installation, and testing of the HDPE pipes began on 23 December 2002 and were completed on 10 February 2003. Trench backfilling, inspection and testing of the yeapiping system were completed by 25 April 2003.



SECTION

CROSS SECTION OF LINER SYSTEM ON-SITE DISPOSAL FACILITY

SCALE: N.T.S.

XREF: 1432x042

NOTE

1. SELECT IMPACTED MATERIAL THICKNESS ABOVE LINER SYSTEM MAY BE DECEASED TO 2 FEET IF THE FIRST LIFT OF MATERIAL TO BE PLACED OVER THE SELECT IMPACTED MATERIAL CONSISTS OF CATEGORY 1 MATERIAL.

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	2-1
PROJECT NO.	GQ1341-03.1
DOCUMENT NO.	-
FILE NO.	1341F2-1

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3. CONSTRUCTION QUALITY ASSURANCE PROGRAM

3.1 Scope of Services

3.1.1 Overview

The scope of CQA services performed by GeoSyntec during the construction of the OSDF Phase IV – Cells 4 and 5 project included:

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

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 OSDF Phase IV - Cells 4 and 5 construction. The CQA activities conducted by GeoSyntec were intended to satisfy the requirements of the following documents:

- "*Certified-For-Construction Technical Specifications, On-Site Disposal Facility Phase IV – Project Number 20104*", 20104-TS-0001, Revision 1, dated March 2002, prepared by GeoSyntec Consultants;
- "*Construction Quality Assurance Plan, On-Site Disposal Facility*", 20100-PL-0006, Revision 1, dated May 2001, prepared by GeoSyntec Consultants;
- "*On-Site Disposal Facility – Phase IV Certified-For-Construction Drawings*", Revision 0, prepared by GeoSyntec Consultants, dated August 2001; and
- "*Impacted Materials Placement Plan, On-Site Disposal Facility*", 20100-PL-007, Revision 3, dated August 2001, prepared by GeoSyntec Consultants.

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 final report. Also included in the appendices are requests for clarifications (RCIs) and nonconformance reports (NCRs).

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 CQA personnel reviewed the Project Documents for familiarity.

3.1.3 CQA Field Operations

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

Earthwork:

- periodically monitoring on-site borrow area soils excavations;
- collecting pre-conformance and conformance test samples of soils considered for use as compacted clay liner, compacted fill, and granular components of the Cells 4 and 5 liner systems for testing;
- performing geotechnical pre-conformance and conformance testing in either the on-site or off-site geotechnical laboratories;
- reviewing and evaluating geotechnical laboratory pre-conformance and conformance test results to ensure compliance with the requirements of the Project Documents;
- establishing acceptable permeability zones (APZs) for each clay stockpile;
- periodically monitoring grading operations on Cells 4 and 5 subgrades;
- monitoring placement and compaction of compacted fill in subgrade areas requiring backfill;
- monitoring final preparation and proofrolling of top of subgrade;
- monitoring trenching operations for installation of the HDPE pipes;
- monitoring placement and compaction of pipe embedment fill and backfill;

- monitoring grading operations (i.e., cutting and filling) on the cell floors;
- 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, textured 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 Fluor Fernald QA and CM and marking damage for replacement or repair;
- collecting and reviewing geosynthetics manufacturers' quality control (QC) 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;
- periodically 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 electrical leak detection testing of completed portions of the Cells 4 and 5 primary liner geomembranes;
- reviewing and commenting on the geomembrane panel layout drawings prepared by Estes;
- monitoring the installation of geotextiles and continuous sewing of adjacent panels;
- monitoring repairs to portions of the geosynthetics that were observed to have defects, or that failed destructive or nondestructive testing; and
- monitoring the placement of the geosynthetics and the backfilling and compaction of compacted clay material in the anchor trench.

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

- tracking the inventory of the liner penetration boxes and perforated 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;
- reviewing source qualification test results on samples of aggregate used in the LCS and LDS layer systems;
- monitoring placement of the aggregate for the LCS and LDS layers;
- monitoring installation of the LCS collection pipe, redundant LCS collection 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 Cells 4 and 5 outlets; and
- monitoring of closed-circuit television (CCT) surveys of the LDS, LCS, and RLCS carrier pipes from VH-4 and VH-5 into Cells 4 and 5, respectively.

Solid HDPE Pipes:

- tracking the delivery of the HDPE pipes stockpiled on the site;
- collecting and reviewing HDPE pipe manufacturer's certification documents to verify compliance with the requirements of the Project Documents;
- visual monitoring of trial welds (including bent strap testing) and production welding of HDPE pipes;
- visual monitoring of the installation of the HDPE pipes for the Cell 6 HMW, and the simultaneous butt-fusion welding of the extension of the dual-containment pipes from Cell 6 outlet to the stub-outs at VH-6; and
- visual monitoring of the hydrostatic pressure and pneumatic testing of the dual-containment piping system extension from VH-6 stub-outs to Cell 6 outlet.

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. Fluor Fernald and/or the appropriate subcontractor 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 assure compliance with the Project Documents.

Upon substantial completion of construction, testing, and documentation of the OSDF Phase IV – Cells 4 and 5 project, interim construction certification letters were prepared and submitted to Fluor Fernald. Copies of the letters are included in Appendix A. This final documentation report includes all construction required by the Project Documents except seeding of completed Cells 4 and 5 slopes.

Items that were completed during the Phase IV construction project but are not included in this CQA final report include the following:

- results of conformance testing performed on screened clay liner and cap material stockpiles for future Cell 2 final cover and Cell 6 liner construction;
- results of pre-conformance testing conducted on test pit samples in the OSDF Sedimentaton Basin No. 2 area, prior to excavation, for future screening and use as clay liner and cap materials for future OSDF cell liner and cap construction projects; and
- other miscellaneous construction work performed by FFC and/or its subcontractors during the 2002-2003 construction projects.

The pre-conformance and conformance test results will be included in the CQA final reports for the appropriate cell liner or final cover system construction projects.

3.1.4 Final Report

This final CQA report was 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. CQA personnel also documented the results of on-site geotechnical laboratory testing conducted as part of the CQA program. In addition, manufacturer quality control (QC) certificates and test results for the geosynthetics and other materials were provided to

system. Estes also prepared geomembrane panel layout drawings. The as-built and panel layout drawings are included in the appendices to 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 D; Volume III contains Appendix E; Volume IV contains Appendix E (continued) through F; Volume V contains Appendices F (continued) through G; Volume VI contains Appendices G (continued) through P; and Volume VII contains Appendices Q through U. A summary of the documentation included in the appendices to the final report is provided below:

- Appendix A: Cells 4 and 5 Interim Construction Certification Letters
- Appendix B: Photographic Documentation
- Appendix C: Weekly Field Reports, Minutes of Meetings, and Correspondence
- Appendix D: Personnel Logs
- Appendix E: Geotechnical Laboratory Test Results
- Appendix F: Manufacturer's Quality Control Documentation
- Appendix G: Field Moisture/Density Test Results
- Appendix H: Geosynthetics Conformance Test Results
- Appendix I: Contractor's Certificate of Acceptance of Subgrade
- Appendix J: Geomembrane Panel Placement Monitoring Logs
- Appendix K: Geomembrane Trial Seam Logs

- Appendix L: Geomembrane Production Seam Logs
- Appendix M: Geomembrane Destructive Seam Test Logs and Laboratory Test Results
- Appendix N: Geomembrane Repair Summary Logs
- Appendix O: Geomembrane Seam and Repair Location Logs
- Appendix P: Electrical Leak Detection Testing Report
- Appendix Q: As-Built and Geomembrane Panel Layout Drawings
- Appendix R: HDPE Pipe Test Logs
- Appendix S: Requests for Clarification of Information (RCIs)
- Appendix T: Design Change Notices (DCNs)
- Appendix U: Nonconformance Reports (NCRs)

3.2 Personnel

3.2.1 Project Personnel

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

Department of Energy (Facility Owner)
- Robert J. Janke, DOE Fernald SWP Team Leader
- Art Murphy, DOE Fernald OSDF Project Manager
- Donald A. Pfister, P.E., DOE Fernald Facility Representative

Ohio Environmental Protection Agency (Regulatory Agency)
- Tom Ontko, Federal Facilities Oversight Representative

Fluor Fernald, Inc. (Owner's Representative and Prime Contractor)

- Tom Beasley, Deputy Director
- Pete Bolig, Safety & Health Representative
- Tom Carr, Construction Coordinator
- J.D. Chiou, Ph.D., P.E., Project Director
- Jeffrey R. Ellis, P.E., Construction Engineer
- Corey Fabricante, Radiological Control Team Leader
- Frank Flack, Construction Contracts Manager
- Michael W. Godber, Quality Assurance Team Leader
- Donald B. Goetz, Construction Engineer
- Kevin S. Harbin, Construction Superintendent
- Alan Hohnhorst, Contracts and Acquisition
- Gregg K. Johnson, Safety & Health Team Leader
- Uday A. Kumthekar, P.E., Engineering/Planning Manager
- Surinder Kumar, P.E., Engineer
- Jeffrey A. Middaugh, Safety & Health Representative
- Janet K. Porter, SDFP Secretary
- Marty Prochaska, Construction Engineer
- Richard Scheper, Quality Assurance
- Perry Richardson, WAO
- Anthony Snider, Soils Project Engineer
- Gordon M. Stumbo, Construction Superintendent
- Harold Swiger, SDFP Team Technical Specialist
- Charles C. VanArsdale, P.E., Project Engineer
- Muriel K. Vigus, Quality Assurance
- Danyel Wells, Construction Administrator
- Jerry Williams, Construction Superintendent
- Eric Woods, Natural Resources/Stewardship Manager
- William A. Zebick, OSDF Construction/Execution Manager

GeoSyntec Consultants (CQA Consultant)

- Sheila Abney, Administrative Assistant
- Kwasi Badu-Tweneboah, Ph.D., P.E., Project Manager
- John F. Beech, Ph.D., P.E., Principal-in-Charge
- Chad Bird, Senior Engineering Technician
- David Evans, Engineering Technician
- David Olomajeye, Engineering Technician
- Kenneth Sparks, Senior Engineering Technician

- Collin P. Sukow, CQA Site Manager
- Christopher Walker, Senior Engineering Technician
- Jeff Williams, Senior Engineering Technician
- T. Byran York, E.I.T., Senior Engineering Technician

Golder Associates, Inc. (off-site soil-geotechnical and geosynthetics laboratory)

- Henry Mock, Laboratory Director
- Barry E. Sigmon, P.G., Laboratory Manager

Soil-Geosynthetic Interaction (SGI) Testing Services

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

The Istre Company, Inc. (Geosynthetics Installer, key personnel only)

- Jerry Istre, Superintendent, Master Seamer
- Hal White, QC Inspector
- Danny White, QC Welding Technician

Leak Location Services, Inc. (Subcontractor, key personnel only)

- Glenn T. Darilek, P.E., Project Manager
- Herman J. Flores, Field Technician
- Martin Morales, Senior Lead Technician

Wise Construction Company (Subcontractor, key personnel only)

- Jerome R. Geiger, Piping Foreman
- James P. Sullivan, Piping Foreman

David E. Estes Engineering, Inc. (Contractor's Surveyor)

- Lynn E. Hirsch, P.L.S., Senior Professional Land Surveyor
- Thomas J. Mack, P.S., E.I.T., Project Surveyor and Engineer

3.2.2 GeoSyntec's On-Site Personnel Schedules

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

- K. Badu-Tweneboah, Ph.D., P.E., Project Manager — 01 April 2002 – April 2003

• C.P. Sukow, CQA Site Manager	01 April 2002 – April 2003
• David Evans, Engineering Technician	01 April 2002 – April 2003
• Chad Bird, Senior Engineering Technician	10 July 2002 – 15 August 2002
• David Olomajeye, Engineering Technician	03 June 2002 – 06 January 2003
• Ken Sparks, Senior Engineering Technician	09 April 2002 – 06 January 2003
• T. Byran York, E.I.T., Senior Engineering Technician	01 April 2002 – 10 April 2002 19 April 2002 – 23 April 2002 12 June 2002 – April 2003
• Christopher Walker, Senior Engineering Technician	01 July 2002 – 02 December 2002 10 January 2003 – April 2003
• Jeff Williams, Senior Engineering Technician	22 July 2002 – 13 October 2002
• Sheila Abney, Administrative Assistant	01 April 2002 – April 2003

4. GENERAL DOCUMENTATION

Documentation and as-built drawings on the results of the CQA monitoring and testing activities performed and/or reviewed by GeoSyntec are contained in the appendices to this report. GeoSyntec's on-site CQA personnel used photographs to record significant events and progress of work during construction of the Phase IV - Cells 4 and 5 project. Photographic documentation of the construction activities is presented in Appendix B.

GeoSyntec's on-site CQA personnel recorded daily events, site conditions, construction progress, and communications on Daily Field Reports. The daily reports prepared by the CQA personnel are not included in the appendices; however, they can be made available upon request. Weekly reports of construction progress prepared by the CQA Site Manager and Resident Engineer are included in Appendix C.

GeoSyntec's key CQA personnel also attended the Weekly Contractor Coordination meetings to discuss construction-related issues and schedules, and review project requirements. Representatives from DOE, Ohio Environmental Protection Agency (OEPA), Fluor Fernald, and GeoSyntec attended these meetings. The minutes from these meetings, and other correspondence related to the Phase IV - Cells 4 and 5 construction project, are included in Appendix C.

Results of CQA monitoring, testing, and documentation performed by CQA personnel during the OSDF Cells 4 and 5 construction were recorded on the appropriate monitoring and data forms presented in the appendices. The relevant appendices will be referenced in this CQA final report.

During construction of the OSDF Cells 4 and 5, RCIs and DCNs that provided design changes and clarifications to the CFC 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 and the Regulatory Agency. Copies of the RCIs and DCNs are presented in Appendix S and Appendix T, respectively.

Finally, all non-conformances associated with the construction were resolved through disposition by the Fluor Fernald CM, Engineering and QA, with concurrence, where appropriate, by the GeoSyntec CQA personnel. Copies of the non-conformance reports (NCRs) that were written during the Phase IV - Cells 4 and 5 construction project are included as Appendix U to this CQA final report.

5. CONSTRUCTION QUALITY ASSURANCE – EARTHWORK

5.1 General

GeoSyntec monitored the construction of the earthwork components associated with the OSDF Phase IV – Cells 4 and 5 project. The components of the project completed during the construction period consisted of Cells 4 and 5 liner system construction; installation of the HDPE pipes for the Cell 6 HMW and dual-containment pipe tie-in from VH-4 and VH-5 to Cells 4 and 5, respectively, and extensions from VH-6 stub-outs to Cell 6 outlet; excavation, screening of clay liner and cap material, and interim restoration of the OSDF borrow area Sub-areas 1 and 2; and excavation and construction of OSDF Sedimentation Basin No. 2. Different earthwork materials were used to construct the various components of the project. These materials included existing subgrade material, compacted fill, compacted clay liner, granular drainage material for the LDS and LCS layers, road base aggregate, riprap, and pipe embedment fill material. The earthwork construction activities using these materials are generally described below.

- Cells 4 and 5 footprints were stripped of topsoil and additional topsoil encountered below proposed subgrade elevations. The stripped topsoil was removed, hauled, and stockpiled in the Cell 7 footprint area.

- Cells 4 and 5 subgrades were 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 re-compacted or undercut and replaced with fill material which was compacted as described below. In addition, geotextile and riprap were used to bridge over excessively soft areas in Cells 4 and 5, and compacted fill was placed and compacted to subgrade design elevations, as described below.

- The cell floors were graded to achieve the required subgrade elevations. The subgrade in areas of the cell floors 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 unit weight, as determined by the standard Proctor compaction

test (i.e., American Society for Testing and Materials (ASTM) D 698). The fill material 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 (ASTM D 698).

- The Cells 4 and 5 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 Cells 4 and 5 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 screened clay material stockpiles in the east field borrow area (EFBA). Each lift 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 (ASTM D 698). The compacted clay liner was compacted at moisture content between +0 and +3 percent of the OMC measured in the standard Proctor compaction test (ASTM D 698). The field moisture content and dry unit weight were also required to fall within the acceptable permeability zone (APZ) established for each screened clay stockpile, in accordance with the Technical Specifications, CQA Plan, the Test Pad Program Final Report (TPPFR) and the TPPFR Addendum. The APZ criteria were used to assure a hydraulic conductivity of less than 1×10^{-7} cm/s. Clay materials used for construction of the compacted clay liner were approved through conformance testing which included remolded hydraulic conductivity testing on composite samples from each stockpile in the off-site geotechnical laboratory and the establishment of an APZ for each clay stockpile.

- The granular components of the Cells 4 and 5 liner systems, 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. Granular drainage materials were approved through conformance testing of samples and review of supplier's certification test results. The material for each layer was placed and tracked in approximately 12-in. (300-mm) thick lifts using an

LGP bulldozer; and 3-ft (0.9-m) thick haul roads were used for heavy traffic loads in order to protect the underlying geosynthetics.

- 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 maximum dry unit weight, as determined by the standard Proctor compaction test (ASTM D 698). The clay wedge layers connecting the cell clay liner and future clay liner were compacted at field moisture contents and dry unit weights falling within the APZ established for each clay stockpile, as previously described. 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.

- The 1-ft (0.3-m) thick protective layer within the Cells 4 and 5 footprints were constructed using impacted material obtained from the Soils Disposal Facility Project (SDFP) excavations and stockpiles. In the impacted runoff catchment areas, 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, obtained from excavation for the OSDF Sedimentation Basin No. 2, was also used to construct the protective layer on the outside slopes of the Cell 5/Cell 6 intercell berm. The protective layer was placed in a 12- to 15-in. (300- to 350-mm) thick loose lift and was tracked with an LGP bulldozer.

- Base aggregate material was used to construct the impacted material haul road and access ramps. The material was obtained from off-site borrow sources, and was approved through review of suppliers' certification test results. The base aggregate material was placed and compacted in general accordance with Items 304.04 and 304.05 of Ohio Department of Transportation (ODOT) Specifications, to meet the requirements of the Technical Specifications.

- Riprap was used to construct drainage channel linings and also used for temporary slope protection and other surface-water management and erosion control (SWMEC) measures. The riprap materials (both Type C and D Dumped Rock Fill) were obtained from off-site borrow sources, and were approved through review of suppliers' certification test results. The riprap

materials were placed in accordance with the requirements of the Technical Specifications.

CQA personnel monitored these earthwork construction activities and performed the appropriate geotechnical testing on 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 testing was performed and documented by CQA personnel. The testing was carried out either: (i) in-place; (ii) on-site, in the geotechnical laboratory; or (iii) in the off-site testing laboratory.

5.2 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 and the regulatory agency (i.e., OEPA). Copies of the RCIs and DCNs for the Phase IV - Cells 4 and 5 project are presented in Appendices S and T, respectively.

5.3 Pre-Conformance Testing Activities

Samples of the brown and gray till were collected from the east field borrow area (EFBA) for the purpose of identifying candidate materials suitable to be screened for clay liner and cap material. The samples were collected from test pits evenly spread throughout the section of the borrow area to be screened. Test pits ranged in depth from 4 to 16 ft (1.2 to 4.8 m) with soil samples collected approximately every 2 ft (0.6 m).

The collected samples were visually described and the test pits were logged. Test pit logging recorded the interface between topsoil, brown till, and the gray till as well as any major features such as sand lenses and perched water that were encountered. The samples were tested for moisture content (ASTM D 2216), particle-size analysis (ASTM D 422), and Atterberg limits (ASTM D 4318). The Unified Soil Classification System (USCS) was used to classify the samples in general accordance with ASTM D 2487.

The results of the pre-conformance sampling and testing for screening clay liner and cap material from sub-areas 2 through 8 of the EFBA are presented in Appendix E. As indicated in Appendix E, the pre-conformance sampling and testing program for the

EFBA was very comprehensive and served as a basis for all future OSDF screening and processing of clay liner and cap material.

5.4 Conformance Testing Activities

5.4.1 General

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

Compacted fill material used in Cells 4 and 5 construction was obtained from designated stockpiles within the OSDF construction areas and from the brown-gray till within the EFBA. Compacted clay liner material was obtained from the screened clay material stockpiles in the EFBA.

The granular drainage materials were obtained from off-site sources. The LCS and LDS drainage layer (No. 78 coarse aggregate) was obtained from Hanson Aggregates (Hanson) Eagle Quarry in Winchester, Ohio. The LCS and LDS drainage corridor material (No. 57 gravel) was obtained from Martin Marietta Aggregates (Martin Marietta) Quarry in Fairfield, Ohio.

The base aggregate material (ODOT No. 304 aggregate) was obtained from the Welch Sand and Gravel, Inc. (Welch) Quarry in Ross, Ohio. The Type C riprap material was obtained from New Point Stone Co., Inc. (New Point) Quarry in Greensburg, Indiana. The additional Type D riprap materials, used for channel lining and other SWMEC measures, were also obtained from Hanson's Highland Quarry in Hillsboro, Ohio.

5.4.2 Test Methods

The following geotechnical tests, when appropriate, were performed on each of the soil components of the Cells 4 and 5 liner systems:

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

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

- Standard Proctor compaction tests were conducted on the soils used for compacted fill and compacted clay liner. 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 establishing the APZ for each clay stockpile.

- Hydraulic conductivity tests were performed on the compacted clay liner material. Tests were conducted on remolded individual and composite samples of screened clay liner material from each stockpile. The remolded hydraulic conductivity tests 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.

- Organic content tests were performed on samples of the topsoil, encountered during Cells 4 and 5 excavations, in general accordance with ASTM D 2974 (See Section 5.5.2).

- Particle-size distribution tests were performed on samples of the coarse-grained soils used for the LCS and LDS drainage layer and the LCS and LDS drainage corridor in general accordance with ASTM C 136. The USCS was used to classify the materials in general accordance with ASTM D 2487.

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

The results of the geotechnical laboratory tests performed on the soil materials used for the Phase IV – Cells 4 and 5 construction project are presented in Appendix E, and summarized in Section 5.4.3.

5.4.3 Summary of Geotechnical Test Results

5.4.3.1 Compacted Fill

A total of 13 index tests (i.e., moisture content, particle-size distribution, Atterberg limits and classification tests) were performed on compacted fill material. The compacted fill material used in construction classified as GC, SC, SM, ML or CL according to the USCS when evaluated in accordance with ASTM D 2487 and the maximum particle size was 5.0 in. (130 mm). A total of 13 standard Proctor compaction tests were performed on fill materials used as compacted fill.

Table 5-1 presents a summary of the geotechnical tests conducted on the fill materials used as compacted fill. Compacted fill was also used as trench backfill for the Cell 6 HMW pipes and the extensions of the dual-containment pipes from VH-6 stub-outs to Cell 6 outlets; and for the protective layer in the Cell 5/Cell 6 intercell berm.

5.4.3.2 Compacted Clay Liner

As required by the Project Documents, clay materials conforming to pre-conformance testing criteria (see Section 5.3) were screened prior to conformance testing. Screened clay material meeting the clay liner and cap material requirements of the Technical Specification is referred to as clay liner and cap material and used for the compacted clay liner construction. A total of 14 screened clay material stockpiles, with in-place volumes (ICY) ranging from approximately 4,870 to 9,680 yd^3 (3,720 to 7,400 m^3), were used for the Cells 4 and 5 construction. The screened clay material stockpiles were designated and labeled as Stockpiles 99-4, 01-1 through 01-10, and 02-1 through 02-3 in the EFBA. Conformance testing was performed on each clay material stockpile, in accordance with the Project Documents.

Index and standard Proctor compaction tests were performed at a minimum frequency of one set per 1,500 yd^3 (1,150 m^3) of stockpiled clay liner material. A total of 68 index tests were performed on the compacted clay liner material to verify that the consistency of the material corresponded to the requirements of the Technical Specifications. The tests indicated a variation in the plasticity index (PI) between 10 and 21, and a variation in clay content (i.e. percent of particles, by weight, finer than 0.002 mm) between 19 and 32 percent. The particle-size distribution and Atterberg limits tests all resulted in a classification of CL (i.e., lean clay) for the clay liner material, according to the USCS.

A total of 68 standard Proctor compaction tests and 34 modified Proctor compaction tests were performed on the stockpiled clay material to establish the average moisture-density relationship, including the line of optimums, for each clay material 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 CQA Plan and Technical Specifications. A total of 14 remolded hydraulic conductivity tests were performed on 14 composite samples with each sample being representative of each clay material stockpile. Remolded hydraulic conductivity testing was also performed on 14 individual samples from select samples to facilitate in the stockpile approval.

The results of the geotechnical laboratory conformance testing performed on the screened clay liner material stockpiles, including the established APZ for each stockpile, are presented in Appendix E. A summary of compacted clay liner properties is presented in Table 5-2, which indicates that the clay liner material meets the requirements of the Project Documents.

5.4.3.3 LCS and LDS Drainage Layer Materials

On-site laboratory particle-size distribution tests were performed on 20 samples obtained from the on-site stockpile for the LCS and LDS drainage layer materials. The laboratory particle-size distribution test results are presented in Appendix E. GeoSyntec also performed off-site laboratory hydraulic conductivity tests and carbonate content tests on representative samples of the LCS and LDS drainage layer materials. A summary of the testing requirements for the LCS and LDS drainage layer materials is presented in Table 5-3.

Based on the testing performed, the granular drainage material used in construction of the LCS and LDS drainage layers classified as GP (i.e., poorly graded gravel) according to the USCS (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 coarse aggregate (except for six samples as indicated in Table 5-3); had a carbonate content of less than 5 percent when tested in accordance with ASTM D 3042 modified with 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 failing results were approved through further evaluation via NCR

No. 20104-002 as indicated on Table 5-3 and Appendix U. The results of the laboratory tests on the LCS and LDS drainage layer material are presented in Appendix E.

5.4.3.4 LCS and LDS Drainage Corridor Material

Three particle-size distribution tests (ASTM C 136), two carbonate content tests (ASTM D 3042), and three hydraulic conductivity tests (ASTM D 2434) were conducted on the LCS and LDS drainage corridor material. Test results are presented in Appendix E, and summarized in Table 5-4. The LDS and LCS drainage corridor material classified as GP according to the USCS (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 gravel; had a carbonate content of less than 5 percent when tested in accordance with ASTM D3042 modified with a pH of 4; and met the hydraulic conductivity requirement of 10 cm/s or greater when evaluated in accordance with ASTM D 2434.

5.5 Field Monitoring Activities

5.5.1 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.

5.5.2 Excavation

CQA personnel monitored excavation operations within Phase IV - Cells 4 and 5 work areas. Topsoil, organic matter (i.e., stumps, roots, or vegetation), and any other deleterious material was excavated and stockpiled on-site prior to construction of the Cells 4 and 5 liner systems. In particular, excessive topsoil that was encountered within the Cells 4 and 5 footprints were removed, loaded in articulated dump trucks, and stockpiled in designated stockpile areas (see Appendix B for photographic documentation). Results of organic content tests performed on topsoil samples are included in Appendix E.

5.5.3 Subgrade

The Cells 4 and 5 subgrade was prepared generally by excavating in-situ soils (including topsoil) and, in certain locations, including areas across the cell floor and

perimeter berms, placement and compaction of compacted fill to the design subgrade elevations and grades. The subgrade was prepared by FFC; the details of the construction are described in the following subsections.

5.5.3.1 Material

The compacted fill material used within the subgrade and perimeter berms consists of fill material from on-site borrow sources described in Section 5.4. The results of standard Proctor compaction tests performed on compacted fill material (see Appendix E) were used as reference for the compaction and testing of the compacted fill and subgrade (see Table 5-1).

5.5.3.2 Construction Procedure

The cell floors were graded to achieve the required subgrade elevations. Isolated areas of excessively soft or loose zones were excavated prior to placement of fill. In most cases, these areas were identified during proofroll, described below. 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 unit weight and within ±3 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698).

The fill material was placed in controlled lifts using Volvo A35C articulated dump trucks and using Caterpillar D-6 LGP bulldozers to spread the material. The horizontal lifts were compacted using a Caterpillar 815 sheepsfoot compactor and sealed with a CS-563 smooth drum roller. During placement and compaction, CQA personnel monitored the contractor's activities, including removal of visible rock particles larger than 5 in. (125 mm) and limiting clod size to 3 in. (75 mm) or less, as required by the Project Documents.

5.5.3.3 Field Testing Activities

Geotechnical Testing

CQA personnel performed in-place nuclear moisture/density tests on compacted lifts of compacted fill and subgrade. These tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. A total of 276 field nuclear moisture/density tests were performed on the compacted fill, including the perimeter berms. The resulting frequency is 1.6 tests/10,000 ft^2/lift, which exceeds the minimum frequency of 1 test/10,000 ft^2/lift required by the CQA Plan (see Table 5-1). In addition, 12 drive

cylinder tests (ASTM D 2937) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 nuclear moisture/density tests.

The results of each field nuclear moisture/density tests were compared to the project requirements of a minimum degree of compaction of 95 percent of the maximum dry unit weight and within ±3 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). The holes left from the moisture/density tests were filled with soil-bentonite mixture. The results of the field moisture/density tests performed on compacted fill are presented in Appendix G, and summarized in Table 5-1.

Proofrolling

Following completion of the subgrade preparation, FFC proofrolled the top of subgrade to detect soft or loose zones, as required by the Project Documents. The proofrolling was performed using a loaded Volvo A35C articulated dump truck with a minimum loaded weight of 20 tons (20.3 tonnes). During proofrolling, the surface was monitored by CQA personnel to confirm the firmness of the top of subgrade for placement of the compacted clay liner.

5.5.3.4 Certification

The surveyed areas of the top of the subgrade were found to be within the project tolerance of -0.3 to +0.1 ft (-0.09 to +0.03 m) from the design elevations, as required by the Project Documents. The as-built top of subgrade certification drawings for Cells 4 and 5, prepared by Estes, is included in Appendix Q.

5.5.4 Compacted Clay Liner

After completing the subgrade construction operations, CQA personnel monitored the placement and compaction of the clay liner material by FFC. The compacted clay liner consisted of a minimum of 3 ft (0.9 m) thick layer, as shown on the CFC Drawings, placed and compacted in lifts, as described on the following pages.

5.5.4.1 Material

The compacted clay liner was constructed using clay liner and cap material from the on-site screened clay material stockpiles in the EFBA described in Section 5.4. As previously described, clay liner and cap materials used for the compacted clay liner were: (i) processed on-site using a bar screening plant and stockpiled in preparation for

transportation to the Cells 4 and 5 construction areas; (ii) a water bar attachment on the screening plant added water to the material to hydrate the clay and maintain the moisture content within the stockpile; and (iii) each stockpile was approved through conformance testing which included hydraulic conductivity testing of remolded composite samples from each stockpile in an off-site geotechnical laboratory and establishment of an APZ (see Appendix E).

5.5.4.2 Construction Procedure

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/cap 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 and cap 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 and cap material in use. This modified APZ was established for each stockpile that was used for the compacted clay liner construction for Cells 4 and 5 liner systems. The construction sequence of the compacted clay liner is described below:

- the subgrade surface and the top surface of each lift of compacted clay were scarified by tracking back and forth with a Caterpillar D-6 LGP bulldozer;
- the clay liner and cap material was hauled from each stockpile in the EFBA 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, the soil stabilizer was used to break up clods of compacted clay; water was added as necessary to increase the moisture content of the clay material within 0 to +3 percent of the OMC as determined by the standard Proctor compaction test (ASTM D 698);
- 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 815 or 825 sheepsfoot compactor making a minimum of six one-way 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 LGP bulldozer was used in conjunction with a laser plane survey system to grade the compacted clay liner surface;
- the final grade was rolled with a vibratory smooth drum roller to seal the top surface of the compacted clay liner; and
- after final grading of the compacted clay surface, the surveyor confirmed final grade elevations.

The compacted clay liner was generally constructed in a minimum of six compacted lifts to a total thickness of 3 ft (0.9 m) minimum, as shown on the CFC Drawings. The contractor periodically added water during or after compacted clay liner placement and compaction to limit drying or desiccation cracking of the surface.

GeoSyntec CQA personnel monitored the compacted clay liner placement and compaction process described above. CQA personnel visually monitored that FFC utilized six or more passes with the compactor across the clay liner lift. CQA personnel also visually monitored that FFC protected completed compacted clay liner from significant drying or the surface from desiccation cracking by routine watering and sealing with the smooth drum roller. If significant drying or cracking of the compacted clay liner surface was observed, FFC was instructed to moisture condition and rework the affected area.

On 28 August 2002, it was discovered that less than 3-ft (0.9-m) thick compacted clay liner had been placed in front of the Cell 5 liner penetration boxes. This area was excavated back down to subgrade elevations and re-surveyed. Once subgrade elevations had been surveyed and certified, the excavated area was backfilled with soil-bentonite mixture. The mixture was placed in multiple lifts and compacted using hand compaction equipment back to the design grades of compacted clay liner. Appendix B

includes photographic documentation of the repairs to the compacted clay liner, which was also addressed through RCI No. 20104-004R (see Appendix S).

5.5.4.3 Field Testing Activities

CQA personnel performed in-place nuclear moisture/density tests as the clay liner material was placed and compacted. The tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. For the maximum disturbed area of approximately 13 acres (5.3 hectares), a minimum of 65 tests per lift were needed to meet the minimum frequency of 5 tests per acre (12 tests per hectare) per lift required by the Project Documents for the Cells 4 and 5 compacted clay liner (see Table 5-2). A total of 933 field moisture/density tests were performed on the Cells 4 and 5 compacted clay liner. In addition, 38 drive cylinder tests (ASTM D 2932) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 nuclear moisture/density tests. The results of each field moisture/density test were checked to see if it was within the established APZ for each clay liner and cap material stockpile, as required by the Project Documents. A total of 63 tests failed to meet the minimum degree of compaction requirement of 95 percent of the maximum dry unit weight and at moisture content of 0 to +3 percent of the OMC, as determined by the standard Proctor compaction tests and within the established APZ. For each failed test, the contractor reworked and re-compacted 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, and summarized in Table 5-2. The holes left from the moisture/density tests, were filled with bentonite granules and clay liner and cap material. The mixture was manually compacted in the holes using a steel rod.

5.5.4.4 Certification

The surveyed areas of the surface of the compacted clay liner were found to be within the tolerances of +0.0 to +0.3 ft (+0.0 to +0.09 m) of the thickness and within ±0.2 ft (±0.06 m) of the grades shown on the CFC Drawings. The as-built compacted clay liner certification drawings, prepared by Estes, are included in Appendix Q.

5.5.5 Leak Detection System Layer

5.5.5.1 Materials

CQA personnel monitored the placement of the LDS layer for the Cells 4 and 5 liner systems. The 1-ft (0.3-m) thick LDS layer was constructed using granular drainage

material obtained from Hanson's Eagle Quarry, as described in Section 5.4. The LDS drainage material was stockpiled in an area south of the Cells 4 and 5 construction areas.

In addition, LDS collection pipe and LDS drainage corridor material were installed in the LDS drainage corridor. The drainage corridor material was obtained from Martin Marietta Aggregates, as described in Section 5.4.

5.5.5.2 Construction Procedure

The construction sequence of the LDS layer was as follows:

- Volvo articulated dump trucks hauled the granular material from the stockpile to the cell areas using a minimum 3-ft (0.9-m) thick haul roads constructed of the granular material;
- the granular material was spread in approximately one 1-ft (0.3-m) thick (loose) lift using Caterpillar D-6R LGP bulldozers; and
- laborers were utilized during the spreading operation to control and prevent wrinkle formation in the underlying geosynthetics.

5.5.5.3 Field Monitoring Activities

During placement of the LDS 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 LGP bulldozers in areas where at least a 1-ft (0.3-m) thick layer of LDS layer material was maintained over the geosynthetics, and that a 3-ft (0.9-m) thick layer of granular drainage layer material was maintained over the underlying geosynthetics in heavily trafficked areas.

5.5.5.4 Certification

Upon completion of grading and tracking using the bulldozer, the surface of the LDS layer was surveyed and certified by Estes. The surveyed areas of the surface of the LDS layer were found to be within the project tolerances of 0.0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built drawings for the top of LDS layer for Cells 4 and 5, prepared by Estes, are included in Appendix Q.

5.5.6 Leachate Collection System Layer

5.5.6.1 Materials

CQA personnel monitored the placement of the LCS drainage layer and drainage corridor materials for Cells 4 and 5. The 1-ft (0.3-m) thick LCS drainage layer was constructed using granular drainage material obtained from Hanson's Eagle Quarry. The granular drainage material was stockpiled in an area south of the Cells 4 and 5 construction area. The LCS drainage corridor material was constructed using granular drainage material obtained from Martin Marietta Aggregates. The granular drainage material was stockpiled in an area south of the Cells 4 and 5 construction area.

5.5.6.2 Construction Procedure

The construction sequence of the LCS layer was as follows:

- Volvo articulated dump trucks hauled the granular 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 material was spread in approximately one 1-ft (0.3-m) thick (loose) lift using Caterpillar D-6R LGP bulldozers; and
- laborers were 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 LDS layer material was maintained over the geomembrane, and that a 3-ft (0.9-m) thick layer of granular drainage layer material was maintained over the geomembrane in heavily trafficked areas.

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

5.5.6.3 Certification

Upon completion of grading and tracking using the bulldozer, the surface of the LCS layer was surveyed and certified by Estes. The surveyed areas of the surface of the LCS layer were found to be within the project tolerances of 0.0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built drawings for top of LCS layer for Cells 4 and 5, prepared by Estes, are included in Appendix Q.

5.5.7 Protective Layer

The 1-ft (0.3-m) thick protective layer was constructed using impacted materials as described in the 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.

The as-built drawings for the top of protective layer for Cells 4 and 5, prepared by Estes, are included in Appendix Q.

5.5.8 Soil Anchorage of Geosynthetics

5.5.8.1 General

GeoSyntec's CQA personnel monitored the placement of material for anchorage of the geosynthetics material around the perimeter of the Cells. Compacted clay liner material was used to provide the permanent anchorage of the geosynthetics. Details of the anchoring are presented below:

5.5.8.2 Perimeter Anchor Trenches

As required by the Project Documents, anchor trenches were constructed around the east and west perimeters of the Cells 4 and 5 construction areas. The construction sequence of the perimeter anchor trenches was as follows:

- a 2-ft (0.6-m) wide by 2-ft (0.6-m) deep anchor trench was excavated along the Cells 4 and 5 perimeter berms, 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 materials and compacted;

- a 2-ft (0.6-m) wide by 2-ft (0.6-m) deep anchor trench was excavated along the Cells 4 and 5 perimeter berms, approximately 7 ft (2.1 m) from the crest of the slope; and

- the primary liner system geosynthetics (i.e., GCL, gemembrane 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 clay stockpiles 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.

The anchor trench backfill was required by the Project Documents to be compacted to a minimum 95 percent degree of compaction of the maximum dry unit weight, 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 field moisture/density tests are included in Appendix G.

TABLE 5-1

COMPACTED FILL MATERIAL PROPERTIES SUMMARY
CELLS 4 AND 5

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 5,000 yd^3	6	13
Standard Proctor Compaction	ASTM D 698	---	1 per 5,000 yd^3	6	13
Moisture	ASTM D 2216 ASTM D 4643	---	1 per 5,000 yd^3	6	13
Soil Classification	ASTM D 2487	GC, SC, SM, ML, CL or CH	1 per 5,000 yd^3	6	13
Atterberg Limits	ASTM D 4318	---	1 per 5,000 yd^3	6	13
FIELD TEST					
Drive Cylinder Soil density Soil moisture	 ASTM D 2937 ASTM D 2216	 ≥95% MDD[3] ± 3% OMC ...	1 per 25 passing nuclear tests	12	12
Nuclear Gauge: Soil density Soil moisture	 ASTM D 2922 ASTM D 3017	 ≥95% MDD ± 3% OMC	2/acre/lift	166	276 (5)

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 61,200 yd^3 for the Phase IV - Cells 4 and 5 construction project.
(3) MDD = maximum dry density (unit weight); OMC = optimum moisture content

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TABLE 5-2

COMPACTED CLAY LINER PROPERTIES SUMMARY
CELLS 4 AND 5

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	68	76
Sieve & Hydrometer					
Percent Finer than 2.0 in.		100%			
Percent Finer than 0.75 in.		≥90%			
Percent Finer than No. 200		≥50%			
Percent Finer than 0.002 mm		≥15%			
Compaction Standard/Modified	ASTM D 698/ ASTM D 1557	—	1 per 1,500/ as required	68/34	76/41
Moisture Content	ASTM D 2216 ASTM D 4643	—	1 per 1,500/ as required	68	76
Soil Classification	ASTM D 2487	CL or CH	1 per 1,500	68	76
Atterberg Limits	ASTM D 4318	$10 \leq PI \leq 40$	1 per 1,500	68	77 (1)
Hydraulic Conductivity:	ASTM D 5084	$\leq 1 \times 10^{-7}$ cm/s	1 per 10,000 or 1 per stockpile		
Individual samples (Remold)				14	14
Composite samples (Remold)				14	14
FIELD TEST					
Drive Cylinder: Soil density Soil moisture	ASTM D 2937 ASTM D 2216	Within APZ and ≥95% MDD 0 - 3% OMC	1 per 25 passing density tests	35	38
Nuclear Gauge: Soil density Soil moisture	ASTM D 2922 ASTM D 3017	Within APZ and ≥95% MDD 0 - 3% OMC	5/acre/lift	405	933[3] (63)
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 (from the Contractor's survey of processed clay material) and the area of the compacted clay liner for the Phase IV - Cells 4 and 5 liner construction.
(3) Failing nuclear density/moisture tests were reworked until passing results were obtained (see Section 5.5.4 of report).

TABLE 5-3

LCS AND LDS DRAINAGE LAYER GRANULAR MATERIAL (NO. 78 STONE) CELLS 4 AND 5

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. 85-100 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 yd^3	20	21 (6)[3]
Soil Classification	ASTM D 2487	GP	1 per 3,000 yd^3	20	21
Carbonate Content	ASTM D 3042	≤5%	1 per 5,000 yd^3	12	15
Hydraulic Conductivity	ASTM D 2434	≥ 0.1 cm/s	1 per 3,000 yd^3	20	21
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 approximately 57,600 yd^3 for the Cells 4 and 5 liner construction project.
(3) The six (6) tests failed to meet the gradation specifications. These failures were resolved through disposition of non-conformance report (NCR) No. 20104-002 presented in Appendix U.

TABLE 5-4

LCS AND LDS DRAINAGE CORRIDOR GRANULAR MATERIAL (NO. 57 STONE) CELLS 4 AND 5

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 5 - 10 No. 8 0 - 5 No. 200 0 - 2	1 per 3,000 yd^3	2	3
Soil Classification	ASTM D 2487	GP	1 per 3,000	2	3
Carbonate Content	ASTM D 3042	≤5%	1 per 5,000	1	2
Hydraulic Conductivity: Granular	ASTM D 2434	≥10 cm/s	1 per 3,000	2	3
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	—	—	—

NOTES: (1) Reference Section 02280 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 4,470 yd^3 for the Cells 4 and 5 liner construction project.

6. CONSTRUCTION QUALITY ASSURANCE - GEOSYNTHETICS

6.1 General

GeoSyntec monitored the installation of the geosynthetics components of the Cells 4 and 5 double-composite liner systems. 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 Fluor Fernald QA and the Construction Manager for review and correction.

The total quantity of geomembrane installed during the Phase IV - Cells 4 and 5 construction, as measured by CQA personnel, was 1,292,820 ft^2 (120,265 m^2), which consists of the primary liner geomembranes and secondary liner geomembranes, including the anchor trenches. The panel layout record drawings for the primary liner and secondary liner geomembranes are presented in Appendix Q.

6.2 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 IV - Cells 4 and 5 are presented in Appendices S and T, respectively.

6.3 CQA of Geosynthetic Clay liner

6.3.1 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 Cells 4 and 5 liner system construction.

For the Bentomat ST GCL, 17 samples (Nos. GCL 02-1 through GCL 02-17) from GCL Lot No. 200202LO and 200203LO were collected for conformance testing. Two representatives from Fluor Fernald and one representative from GeoSyntec visited the CETCO plant in Lovell, Wyoming to observe production, review procedures, and sample material in January 2002. All of the 17 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 Golder Testing Laboratory, Atlanta, Georgia for hydraulic conductivity testing and to SGI Testing Services, Norcross, Georgia for direct shear testing. Based on the conformance sampling and testing results, including the supplier's testing, the lots stated above were approved for construction.

The conformance test results and the manufacturer's quality control (QC) certificates were reviewed by CQA personnel. A summary table for Cells 4 and 5 GCL approval is presented in Table 6-1. The manufacturer's QC documentation is presented in Appendix F. GeoSyntec's conformance test results are also presented in Appendix H. A summary of the physical properties of the GCL and the conformance test frequency is presented in Table 6-2.

6.3.2 Field Monitoring Activities

6.3.2.1 Delivery and On-Site Storage

Upon delivery, GCL rolls were unloaded in a laydown area located in the northeast corner of the OSDF 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 CM 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.

6.3.2.2 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 I);
- 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 were 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 Dry bentonite granules were applied to the repaired area. In areas where premature hydration of the GCL was detected, the GCL was removed and replaced with new approved material.

On 26 and 27 September 2002, a major storm event resulted in about 5.5 in. (14 cm) of rainfall at the FEMP site. As a result, both Cell 4 and Cell 5 were flooded with rainwater to the center of each cell. The water backed up and covered the tie-in seam of the primary geomembrane liner between the east and west half of Cell 4. This tie-in seam had not yet been welded together and water seeped through to the underlying primary GCL. Approximately 6,000 ft^2 (560 m^2) of GCL was hydrated beyond project specifications. The primary geomembrane liner was cut open to expose and remove the hydrated primary GCL. The hydrated primary GCL was removed and replaced with new material and the primary geomembrane liner was repositioned and capped. Appendix B presents photographic documentation on the inspection, removal, and replacement of the hydrated GCL.

6.4 CQA of Geomembrane

6.4.1 Conformance Testing and Documentation

The 80-mil (2.0-mm) thick textured HDPE geomembrane was supplied by GSE Lining Technology, Inc, (GSE) Houston, Texas. Prior to Cells 4 and 5 construction, geomembrane conformance samples were taken randomly from the 80-mil (2.0-mm) thick HDPE textured geomembrane rolls used to construct the liner systems. A total of 20 conformance samples were obtained by CQA personnel at the manufacturing plant prior to delivery to the site. These samples represented 10 lots of geomembrane, which comprised 187 geomembrane rolls. The total number of conformance samples exceeds the minimum acceptable sampling 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 Golder Testing Laboratory 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 F. The geomembrane manufacturer's roll numbers, GeoSyntec's conformance sample logs, and Golder's conformance test results are presented in Appendix H. A summary of the physical properties of the geomembrane and the conformance test results are presented in Tables 6-3.

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 Cells 4 and 5. The certification letter is presented in Appendix F. The geomembrane manufacturer's roll numbers, GeoSyntec's conformance sample logs, and Golder's conformance test results are presented in Appendix H. A summary of the physical properties of the geomembrane and the conformance test results are presented in Tables 6-3.

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 Cells 4 and 5. The certification letter is presented in Appendix F.

6.4.2 Field Monitoring Activities

6.4.2.1 Delivery and On-Site Storage

Upon delivery to the site, geomembrane rolls were stored in a laydown area located to the northeast of the OSDF 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 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.

6.4.2.2 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 CM to assure no damage to the GCL. The installer generally deployed the geomembrane panels from: (i) south to north across the Cell 5/Cell 6 intercell berm; and (ii) east to west across the cell floor and in accordance with the approved panel layout drawings. 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 repairs were complete.

On 19 September 2002, heavy winds overnight caused an uplift of the primary geomembrane liner resulting in large wrinkles up to 2 ft (0.6 m) high running the width of Cell 4 and into Cell 5. TIC used a front end loader and spreader bar to strap the edges of the primary geomembrane liner to pull out the wrinkles. All of the wrinkles were eliminated and there was no need to cut the primary geomembrane liner for further repairs. Appendix B presents photographic documentation on the removal of the wrinkles that developed from the heavy winds.

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

6.4.2.3 Trial Seams

Prior to production seaming, the installer prepared geomembrane trial seams at the beginning of each seaming period, and at least once each four hours, for each piece of 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. (20 kN/m) and the observation of a Film Tear Bond (FTB), and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (26 kN/m); and the observation of a FTB;

Extrusion

- *Peel test* - a minimum bonded seam strength of 84 lb/in. (15 kN/m); and the observation of a FTB, and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (26 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 285 trial seams were observed by CQA personnel during Cells 4 and 5 construction. A total of 205 trial seams were made using double-track fusion (i.e., hot wedge) welders and 180 were made using extrusion welders. A total of 12 trial seams failed (11 fusion seams and 1 extrusion seam). 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 K.

6.4.2.4 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 L.

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 Cells 4 and 5 construction season. Production seaming activities were not performed below 40°F (5°C) during the Cells 4 and 5 construction project.

6.4.3 Nondestructive Seam Testing

6.4.3.1 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 6.4.5 of this report.

6.4.3.2 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 6.4.5 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.

6.4.3.3 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.

When nondestructive testing indicated repairs were necessary, repairs were made in accordance with procedures presented in Section 6.4.5 of this report and the vacuum-box testing repeated. Vacuum test logs are presented in Appendix L.

6.4.4 Destructive Seam Sample Testing

6.4.4.1 Scope

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

A total of 273 geomembrane seam sample locations were identified during Cells 4 and 5 construction; 98 passing and 53 failing tests on the secondary liner geomembranes and 81 passing and 41 failing tests on the primary liner geomembranes. Approximately 76,532 linear ft (23,342 linear meters) of seams were constructed. This corresponds to an approximate sample frequency of one per 430 linear feet (130 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 Film Tear Bond (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. (20 kN/m) and the observation of a FTB; and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (26 kN/m); and the observation of a FTB;

Extrusion

- *Peel test* - a minimum bonded seam strength of 84 lb/in. (15 kN/m); and the observation of a FTB; and
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (26 kN/m); and the observation of a FTB;

In addition, if at least 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.

6.4.4.2 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.

6.4.4.3 Test Results

Off-site laboratory testing of geomembrane seam test samples was performed in accordance with the CQA Plan at the Golder 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 and outside tracks. Additionally, five specimens were tested for shear strength. The seam-strength criteria and the acceptance/rejection criteria described in Section 6.4.4.1 were used.

For Cells 4 and 5, 94 failures were recorded on the initial destructive samples; 61 failures occurred in the field test strips and 33 failures occurred in the laboratory destructive samples (Table 6-4). 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. 110 additional seam samples were obtained to isolate failures and on reconstructed seams, 47 on the primary liner geomembranes and 63 on the secondary liner geomembranes, as indicated in Table 6.4. Seams having failing destructive samples were repaired using procedures present in Section 6.4.5. The destructive seam test sample locations were also repaired using the procedure presented in Section 6.4.5. The destructive seam test results and a summary of the number of samples obtained are presented in Appendix M.

6.4.5 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; and
- spot-extruding impact damage or other minor scratches.

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 N presents repair summary logs for the secondary liner geomembranes and the primary liner geomembranes for Cells 4 and 5. Seam and panel repair locations are presented in Appendix O. Complete panel layout drawings indicating the location of seam and panel repairs is shown on the Record Drawings presented in Appendix Q.

6.4.6 Electrical Leak Detection Testing

The electrical leak detection testing was performed on the Cells 4 and 5 primary liner geomembranes. The method uses the flow of electrical current to detect leaks or breaches in a geomembrane liner. The leak detection testing was performed by Leak Location Services, Inc. (LLSI) of San Antonio, Texas, as a subcontractor to FFC. Sixteen (16) leaks were detected in the primary liner geomembranes that were tested. (Some of these leaks were detected in areas that had not undergone complete repairs and QA/QC, as required by the Project Documents.) Appendix P presents a report on the electrical leak detection testing which was conducted as part of the OSDF Phase IV - Cells 4 and 5 liner systems construction.

6.5 CQA of Geotextile

6.5.1 Conformance Testing and Documentation

Three types of geotextile were used in construction of Cells 4 and 5:

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

- a needle-punched 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., Spartanburg, South Carolina; 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., Spartanburg, South Carolina.

CQA personnel obtained 28 conformance samples from the 402 geotextile rolls delivered to the site. Ten (10) conformance samples were obtained from 144 rolls of geotextile filter, 16 conformance samples were obtained from 237 rolls of geotextile cushion, and 2 conformance samples were obtained from 21 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 Golder 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 F. The

conformance test results are presented in Appendix H. A summary of the properties of the geotextile material and the conformance test results for the geotextile fiter, geotextile cushion, and supplemental geotextile cushion is presented in Tables 6-5, 6-6, and 6-7, respectively.

6.5.2 Field Monitoring Activities

6.5.2.1 Delivery and On-Site Storage

Upon delivery to the site, geotextile rolls were stored in an area located northeast of the OSDF 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.

6.5.2.2 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 overlapped 6 in. (150 mm) and sewn.

6.6 CQA of Liner Penetraton Boxes

Cells 4 and 5 liner penetration boxes were fabricated by Plastic Fusion Fabrications, Inc. (PFFI), Huntsville, Alabama. GeoSyntec reviewed shop drawings and fabrication procedures prior to production. Liner penetration boxes were vacuum 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 F. Vacuum 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 6.4.3.3. CQA personnel monitored the installation and testing activities for the liner penetration boxes.

6.7 CQA of Perforated 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 connects to VH-4 and VH-5 for Cells 4 and 5, respectively.
- RLCS 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 connects to VH-4 and VH-5 for Cells 4 and 5, respectively; 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 which connects to VH-4 and VH-5 for Cells 4 and 5, respectively.

6.7.1 Pipe Conformance Testing and Documentation

The LCS and LDS pipes were delivered to the site during Cells 4 and 5 construction. Lee Supply Co., Inc. (Lee Supply) of Charleroi, Pennsylvania 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 F. 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.

6.7.2 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 southwest of Cell 5. 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 heating plate;

- the ends of the pipe sections were heated for approximately one minute using a 400 to 425°F (204 to 218°C) heating plate;
- the welder quickly removed the heating plate 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 Cells 4 and 5 areas the perforated piping system was constructed to allow drainage toward the liner penetration boxes, located at the west end of each 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 each of Cells 4 and 5 areas:

- 620 ft (189 m) of 6-in. (150-mm) nominal diameter HDPE SDR-11 LDS perforated pipe;
- 620 ft (189 m) of 6-in. (150-mm) nominal diameter HDPE SDR-11 LCS perforated pipe; and
- 17 ft (5.2 m) of 6-in. (150-mm) nominal diameter HDPE SDR-11 RLCS perforated pipe.

The HDPE piping within Cells 4 and 5 were connected to the liner penetration boxes described in Section 6.6. 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 RLCS 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 Cells 4 and 5 via gravity pipeline to the valve houses.

TABLE 6-1

GEOSYNTHETIC CLAY LINER (GCL) CONFORMANCE TESTING APPROVAL SUMMARY
CELLS 4 AND 5

Sample ID	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)
			Direct Shear	Hydraulic Conductivity						
L-02-1	200202LO	138	117	130 151	PASS	PASS	116-145, 151-165	2 May 2002, 5 May 2002	44	99,000
GCL-02-2	200202LO	188	210	181 197	PASS	PASS	166-195,197-201, 209-217	6 May 2002, 2 May 2002	44	99,000
GCL-02-3	200202LO	241	252	238 255	PASS	PASS	218-261	2 May 2002	44	99,000
GCL-02-4	200202LO	283	302	272 294	PASS	PASS	259-286, 292-310	21 May 2002	44	99,000
GCL-02-5	200202LO	332	347	328 345	PASS	PASS	311-312, 314-355	16 May 2002, 21 May 2002	44	99,000
GCL-02-6	200202LO	376	397	362 384	PASS	PASS	356-376, 382-404	14 May 2002, 16 May 2002	44	99,000
GCL-02-7	200202LO	425	442	418 435	PASS	PASS	405-432, 434-447, 453-454	6 May 2002, 14 May 2002	44	99,000
GCL-02-8	200202LO	475	492	474 491	PASS	PASS	455-498	6 May 2002, 14 May 2002	44	99,000
GCL-02-9	200202LO	516	543	508 525	PASS	PASS	499-536, 543-548	2 May 2002, 14 May 2002	44	99,000
GCL-02-10	200202LO	567	588	565 582	PASS	PASS	549-592	2 May 2002	44	99,000
GCL-02-11	200202LO	610	638	599 621	PASS	PASS	593-614, 620-641	2 May 2002, 6 May 2002	44	99,000
GCL-02-12	200203LO	662	683	653 670	PASS	PASS	642-653, 655-686	2 May 2002, 6 May 2002	44	99,000
GCL-02-13	200203LO	706	728	704 721	PASS	PASS	687-694, 696-731	2 May 2002	44	99,000
GCL-02-14	200203LO	752	773	738 755	PASS	PASS	732-749, 751-776	2 May 2002	44	99,000
GCL-02-15	200203LO	796	819	789 807	PASS	PASS	777-804, 806-821	2 May 2002, 6 May 2002	44	99,000
GCL-02-16	200203LO	839	863	824 841	PASS	PASS	822-832, 834-866	6 May 2002	44	99,000
GCL-02-17	200203LO	888	888	880 897	PASS	PASS	867-870, 876-905	6 May 2002	34	76,500

Notes:
1. CQA Roll No. is roll used for conformance testing (direct shear and hydraulic conductivity).
2. MQC Roll No. is roll used for manufacturer's QC testing (direct shear and hydraulic conductivity).
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 Phase IV – Cells 4 and 5 liner construction.
5. Square footage for total number of rolls given.

TABLE 6-2

GEOSYNTHETIC CLAY LINER PHYSICAL PROPERTIES SUMMARY
CELLS 4 AND 5

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 6243	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	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	$\leq 5x10^{-9}$	$\leq 5x10^{-9}$	40,000	100,000
Fluid Loss (ml)	ASTM D 5891	18 max	≤ 18	40,000	NA
Bentonite Free Swell (ml/2g)	ASTM D 5890	24	≥ 24	40,000	NA
Tensile Strength (lb/in.)	ASTM D 4595	35	≥35	40,000	NA

Total No. of Bentomat ST Rolls Delivered to Site: 738 Total No. of Conformance Samples: 17

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 GCC 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 Cells 4 and 5 liner construction. 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.

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TABLE 6-3

80-MIL THICK HDPE GEOMEMBRANE (TEXTURED) PROPERTIES SUMMARY CELLS 4 AND 5

DESCRIPTION	TEST STANDARD	MANUFACTURER 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	42	17	187	20	234.5	202.3
Elongation at Yield (%)	ASTM D 638[5]	13	≥12	40,000	100,000	42	17	187	20	17.7	14.8
Break Strength (lb/in.)	ASTM D 638[5]	324	≥120 [6]	40,000	100,000	42	17	187	20	301	188.6
Elongation at Break (%)	ASTM D 638[5]	560	≥100	40,000	100,000	42	17	187	20	601	367
Thickness (mil)	ASTM D 5994	80 nominal 76 min.	Avg. 80 Min. 76	40,000	100,000	42	17	187	20	94	80
Specific Gravity (NA)	ASTM D 792 or ASTM D 1505	0.940	≥0.935 (resin) ≥0.940 (sheet)	40,000	100,000	42	17	48	20	0.945	0.942
Tear Resistance (lb)	ASTM D 1004 Die C Puncture	60	≥56	40,000	NA	42	NA	187	NA	NA	NA
Puncture Resistance (lb)	ASTM D 4833	120	≥120	40,000	NA	42	NA	187	NA	NA	NA
Carbon Black Content (%)	ASTM D 1603	2.0	2-3	40,000	100,000	42	17	48	20	2.71	2.16
Carbon Black Dispersion	ASTM D 5596	Category 1 or 2	Category 1 or 2	40,000	100,000	42	17	48	20	CAT. 1	CAT. 2
Low Temperature Brittleness (°C)	ASTM D 746B	-75	-60 max.	400,000	NA	4	NA	5	NA	NA	NA
Dimensional Stability (%) (@ 212°F, 15 min.)	ASTM D 1204	±2 max.	±2 max.	400,000	NA	4	NA	5	NA	NA	NA
NCTL (hr)[6]	ASTM D 5397	500	≥500	400,000	NA	4	NA	5	NA	NA	NA
Asperity Height	GRI GM12	7	≥7	40,000	NA	42	NA	93	NA	NA	NA

Total Number of Rolls Delivered to Site: 187 (1,683,000 ft^2) Total Number of Conformance Samples: 20

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 1,683,000 ft^2 for the Cells 4 and 5 liner installation.
(3) GSE Lining Technologies, Houston, Texas is the geomembrane supplier. Roll dimensions are 22.5 ft. x 400 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.

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TABLE 6-4
80-MIL THICK HDPE GEOMEMBRANE (PRIMARY/SECONDARY) (TEXTURED)
SEAM PROPERTIES SUMMARY
CELLS 4 AND 5

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS		REQUIREMENTS	APPROXIMATE NUMBER OF TESTS REQUIRED
		Fusion	Extrusion		
Panel Deployment	-	-	-	Ambient placement temperatures are between 40°F and 104°F.	Assumption used for destructive seam testing is that each roll is approximately 22.5 ft by 400 ft (avg.)
Trial Seams: (peel)	ASTM D 6392	FTB 115 ppi	FTB 84 ppi	Prior to seaming period every 4 hours, or if seaming apparatus is turned off.	Minimum of: 2 peel per trial seam 2 shear per trial seam
(shear)	ASTM D 6392	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 6392	FTB 115 ppi	FTB 84 ppi	500 lin. ft	secondary min. of 82	88	secondary 31	secondary 22	secondary 63	secondary 151
	ASTM D 6392	FTB 151 ppi	FTB 151 ppi		primary min. of 72	75	primary 30	primary 11	primary 47	primary 122

Note: (1) Reference Section 02770 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.
(3) FTB = Film Tear Bond (maximum 10 percent seam separation)

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TABLE 6-5

NONWOVEN GEOTEXTILE (7 oz/yd^2) FILTER PROPERTIES SUMMARY CELLS 4 AND 5

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2]				RANGE OF 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	20	10	21	10	9.4	7.0
Mullen Burst Strength (psi)	ASTM D 3786	400	≥350	50,000	100,000	20	10	21	10	463	334
Grab Strength (lb)	ASTM D 4632	200	≥180	50,000	100,000	20	10	21	10	283	183
Tear Strength (lb)	ASTM D 4533	85	≥75	50,000	100,000	20	10	21	10	186	76
Puncture Strength (lb)	ASTM D 4833	130	≥75	50,000	100,000	20	10	21	10	148	109
Apparent Opening Size (mm) (A.O.S.)	ASTM D 4751	0.180	≤0.212	100,000	100,000	10	10	10	10	0.212	0.135
Permittivity (sec^{-1})	ASTM D 4491	1.50	≥0.5	100,000	100,000	10	10	11	10	2.86	0.88
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: 144

Total Number of Conformance Samples: 10

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 972,000 ft^2 available for Cells 4 and 5 installation.
(3) Roll dimensions are 15 ft by 450 ft for 7-oz/yd^2 geotextile manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina.
(4) MARV = (minimum average roll value), 95 percent lower confidence

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TABLE 6-6

NONWOVEN GEOTEXTILE (10 oz/yd^2) CUSHION PROPERTIES SUMMARY CELLS 4 AND 5

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2]				RANGE OF 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	10	≥10	50,000	100,000	32	16	35	16	17.4	10.0
Burst Strength (psi)	ASTM D 3786	510	≥450	50,000	100,000	32	16	35	16	653	467
Grab Strength (lb)	ASTM D 4632	250	≥225	50,000	100,000	32	16	35	16	357	255
Tear Strength (lb)	ASTM D 4533	100	≥90	50,000	100,000	32	16	35	16	205	95
Puncture Strength (lb)	ASTM D 4833	160	≥120	50,000	100,000	32	16	35	16	210	151
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: 237

Total Number of Conformance Samples: 16

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 1,599,750 ft^2 available for Cells 4 and 5 liner installation.
(3) Roll dimensions are 15 ft by 450 ft for 10-oz/yd^2 geotextile manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

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TABLE 6-7

NONWOVEN GEOTEXTILE (16 oz/yd^2) SUPPLEMENTAL CUSHION PROPERTIES SUMMARY CELLS 4 AND 5

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	3	2	4	2	20.1	16.6
Burst Strength (psi)	ASTM D 3786	800	≥700	50,000	100,000	3	2	4	2	836	784
Grab Strength (lb)	ASTM D 4632	380	≥350	50,000	100,000	3	2	4	2	667	432
Tear Strength (lb)	ASTM D 4533	145	≥120	50,000	100,000	3	2	4	2	325	127
Puncture Strength (lb)	ASTM D 4833	240	≥180	50,000	100,000	3	2	4	2	350	253
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: 21

Total Number of Conformance Samples: 2

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 141,750 ft^2 available for Cells 4 and 5 liner installation.
(3) Roll dimensions are 15 ft by 450 ft for 16-oz/yd^2 geotextile manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

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7. CONSTRUCTION QUALITY ASSURANCE – SOLID HDPE PIPES

7.1 General

GeoSyntec monitored the installation of the solid HDPE pipes for the Phase IV – Cells 4 and 5 construction project. Installation activities that were monitored by GeoSyntec CQA personnel included the following:

- 6-in. (150-mm) nominal diameter HDPE SDR-11 perforated pipe connected to 6-in. (150-mm) nominal diameter HDPE SDR-11 solid-wall pipe components of the HMW for Cell 6 liner;
- 6-in. (150-mm) nominal diameter HDPE SDR-11 45-degree mitered lateral, solid-walled cleanout pipe and 10-in. (250-mm) nominal diameter HDPE SDR-11 solid-wall riser pipe components of the HMW for Cell 6 liner;
- tie-in of approximately 140-ft (43-m) long HDPE SDR-11 dual-containment (6-in. (150-mm) diameter carrier inside a 10-in. (250-mm) diameter containment) piping systems for the LDS, LCS and RLCS lines from the stub-outs at VH-6 to Cell 6 outlet, using simultaneous thermal butt-fusion joint procedures;
- hydrostatic and pneumatic pressure testing of the dual-containment piping systems;
- trench backfilling, which included embedment fill, compacted fill, and concrete placement; and
- CCT video surveys and inspections of the LDS, LCS, and RLCS carrier pipes from VH-4 into Cell 4, and from VH-5 into the Cell 5; these were monitored by CQA personnel, as described below.

7.2 Pipe Conformance Testing and Documentation

The pipes for the Phase IV project were manufactured by Chevron Phillips Chemical Company, LP of Pasadena, Texas, and supplied by Lee Supply. The manufacturer provided the QC certifications for each lot of pipe supplied. The manufacturer's QC certificates are presented in Appendix F. CQA personnel reviewed this documentation and verified that the pipe property data were in compliance with the requirements of the Project Documents.

7.3 Field Monitoring Activities

7.3.1 Delivery and Placement

Upon delivery to the site, the pipes were placed in laydown areas approved by the Construction Manager. The pipes were transported from the laydown area to the construction area by a track hoe or a front-end forklift using nylon straps. The pipe was temporarily stored adjacent to the construction area.

Prior to installation, the approximate lengths of each pipe type were constructed in the laydown areas or construction areas. The pipe sections were joined using thermal butt-fusion welding techniques. The CQA activities associated with the pipe joining techniques are described below.

CQA personnel 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 heating plate;
- the ends of the pipe sections were heated for approximately one minute using a 400 to 425°F (204 to 218°C) heating plate;
- the welder quickly removed the heating plate and joined the pipes with pressure to create a roll back bead;
- the butt-fusion weld was allowed to cool for a minimum period of 30 minutes, 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 manufacturers' procedures (see pipe manufacturer's submittal in Appendix F).

The above procedures were generally used to separately join nominal lengths of the 6-in. (150-mm) pipe and the 10-in. (250-mm) diameter pipes for the HMWs. For the dual-containment pipes for extension to Cell 6 outlet, however, the carrier pipe was already centralized inside the containment pipe. Nominal sections of these dual-containment pipes as well as the tie-in to VH-6 stub-outs were simultaneously joined using the Simultaneous Butt-Fusion Welding procedure (see Appendix F).

The constructed sections of each pipe segment were then placed into the trench. The width and depth of the trench for the pipeline varied with the location and the number of additional pipes that shared the common excavation. Embedment fill was placed in nominal 7-in (175-mm) thick loose lifts up to one lift over the pipe. The top of the pipe was surveyed to confirm compliance with the pipe grades and tolerances required by the Project Documents. The as-built survey data were reviewed by CQA personnel prior to placement of additional lifts of embedment fill over the pipe. The as-built survey data, provided by Estes, are included in Appendix R.

Compacted fill (cohesive material) was then used as backfill to final grade. The backfill was placed in approximately 8-in. thick loose lifts. Hand-operated compaction equipment was used to achieve compaction of the embedment and trench backfill materials. Details of the placement and compaction of the embedment fill and trench backfill materials are discussed in the following section.

7.3.2 Testing Activities

As part of the CQA activities, tests were performed on the installation of the HDPE pipes for the Phase IV project. The following tests were conducted or monitored by CQA personnel for the compacted trench backfill, embedment fill, or piping systems:

- Particle-size distribution and classification tests were performed on samples of compacted trench backfill and embedment fill materials as described in Section 5.3.
- In-place nuclear moisture/density tests were conducted on the compacted fill used in backfilling the pipe trenches; results are included in Appendix G.
- Bent strap tests were performed on trial welds made each day to confirm joint integrity, operator procedure, and fusion machine set-up. CQA personnel monitored the bent strap tests performed by Wise.

- Preliminary pneumatic and final hydrostatic pressure tests were conducted on the dual-containment pipes of LDS, LCS, and RLCS lines from VH-6 stub-outs to Cell 6 outlet. These tests were monitored by CQA personnel and are discussed below.

CQA personnel monitored the bent-strap and pressure testing performed by Fluor Fernald and Wise. The bent-strap test was performed on trial welds by cutting a specimen through the joint area; visually inspecting the cut surface of the pipe at the joint for voids or non-bonded areas; and bending the specimen 180 degrees so that the ends of the specimen touch to verify if the joint holds. Results of the bent strap tests are presented in Appendix R.

A 10-psi (69 kPa) pneumatic test was initially performed as a preliminary test to check each joint. Final hydrostatic pressure tests were then performed after the complete sections of the dual-containment pipes for the LDS, LCS, or RLCS line were installed. For these tests, the contractor typically tested the pipes with water to minimum test pressures of 60-psi (414 kPa) for the carrier pipe and 15-psi (103 kPa) for the containment pipe.

CQA personnel monitored the hydrostatic pressure tests that consisted of pressurizing the pipes over a 4-hour period, at 70-psi (483 kPa) internal pressure for the carrier pipe and 25-psi (173 kPa) internal pressure for the containment pipe, on sections of the installed pipe. After holding the pipe at the test pressure over a 4-hour period, the test pressure was dropped by 10 psi (69 kPa), monitored for one hour for any drop (greater than 5 percent of target value) or visible leaks.

The pressure test results and CQA documentation from the installation of the HDPE pipes are presented in Appendix R.

CQA personnel also monitored the CCT video surveys and inspections of the LDS, LCS, and RLCS carrier pipes from VH-4 and VH-5 to Cells 4 and 5, respectively. The video surveys were performed after completion of final hydrostatic testing and placement of the protective layer, as required by the Project Documents. Copies of the CCT videotapes of the carrier pipes were made available to GeoSyntec CQA personnel to prepare the CCT video survey and inspection logs presented in Appendix R.

In addition to the above-mentioned tests, CQA personnel performed on-site slump and air content tests on the concrete loads delivered to the site for Cells 5 and 6 HMW cover slabs as well as the principal spillway riser footing at the Sedimentation Basin No. 2. Concrete test cylinders, during concrete placement for the principal spillway riser

footing, were prepared and tested by an off-site material testing laboratory (Fuller, Mossbarger, Scott and May Engineers, Inc., Cincinnati, Ohio). The concrete cylinder test results were reviewed by CQA personnel to confirm compliance to the Project Documents. Concrete test results are presented in Appendix R.

8.0 SUMMARY AND CONCLUSIONS

Construction of the OSDF Phase IV – Cells 4 and 5 construction project for the FEMP was carried out during the period from 4 April 2002 to 25 April 2003. During this time, GeoSyntec provided on-site CQA personnel to monitor the construction of the project. 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, and protective layer placement);
- geosynthetics (installation of GCL, primary liner and secondary liner geomembrane, and geotextile layers);
- leachate collection system (installation of LDS, LCS, and RLCS collection pipes and liner penetration boxes);
- installation of HMW pipes for Cell 6 liner;
- tie-in of the LDS, LCS, and RLCS dual-containment pipes for the VH-4 and VH-5 in Cell 4 and Cell 5 outlets, respectively; and
- extensions of LDS, LCS, and RLCS dual-containment pipes from VH-6 stub-outs to Cell 6 outlet.

During construction of the above components, CQA personnel verified that conformance and CQA testing were performed on the construction materials at the frequencies required in 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, and that all non-conformances associated with the construction were resolved through disposition by the Fluor Fernald Construction Manager with concurrence by the Fluor Fernald Engineering, Quality Assurance and the Resident Engineer. Copies of the non-conformance reports (NCRs) written during construction of the Phase IV – Cells 4 and 5 project are included as Appendix U to this CQA final report.

Based on GeoSyntec's understanding of the project requirements, the results of testing conducted as part of the CQA monitoring activities, and the documentation by

GeoSyntec's on-site CQA personnel as described in this report, it is concluded that the Phase IV – Cells 4 and 5 construction project for the OSDF was constructed in general accordance with the Project Documents (i.e., Technical Specifications, Construction Drawings, and all applicable DCNs).

STATE OF OHIO
KWASI BADU-TWENEBOAH
E-55354
REGISTERED PROFESSIONAL ENGINEER

Kwasi Badu-Tweneboah, Ph.D., P.E.
Project Manager
Ohio P.E. No. E-55354

12 June 2003

REFERENCES

Fluor Daniel Fernald, "*Leachate Conveyance System Leak Investigation*", Prepared for United States Department of Energy Fernald Environmental Management Project Fernald, Ohio, April 1999.

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APPENDIX A

Cells 4 and 5 Interim Construction Certification Letters

GEOSYNTEC CONSULTANTS

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7 November 2002

Mr. William (Bill) A. Zebick
Construction Manager
Fluor Fernald, Inc.
P.O. Box 538704
MS:: 64
Cincinnati, Ohio 45253-8704

Subject: Interim Construction Certification
Phase IV Cells 4 and 5 Construction Project
On-Site Disposal Facility
Subcontract No. 95PS005028

Dear Mr. Zebick:

GeoSyntec Consultants (GeoSyntec) has provided construction quality assurance (CQA) and construction quality control (CQC) services during the Phase IV - Cells 4 and 5 construction project at the Fernald Environmental Management Project (FEMP) site. The purpose of this letter is to document that, based on the CQA and CQC activities performed by GeoSyntec, construction of the Cell 4 liner system is substantially complete.

GeoSyntec CQC personnel have monitored, tested, and documented installation of the soils and geosynthetics components of the Cell 4 liner system, including the prepared subgrade, compacted clay liner, granular leachate collection and detection layers, geosynthetic clay liners, geomembrane liners, geotextile cushion and filter layers, and leachate collection piping systems. Field reports, logs, geotechnical and geosynthetic testing reports, and other associated documentation have been reviewed for accuracy and completeness. GeoSyntec is in the process of completing a final certification report including CQC documentation and record drawings on the construction of the Phase IV Cells 4 and 5 construction project. The final certification report, which will include documentation on the placement of the protective layer component of the Cell 4 liner system, as well as completion of Cell 5 liner system, will be submitted at the end of the 2002 construction season.

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Based on our observations and documentation, the OSDF Cell 4 liner system construction has been completed in general accordance with the project specifications, drawings, CQA Plan, and approved design and/or specification changes. The construction has been in full compliance with applicable or relevant and appropriate requirements (ARARs), functional requirements, and general design requirements described in the Design Criteria Package developed and approved during the design process. On the basis of our observations and testing it is anticipated that Cell 4 is ready to begin receiving impacted material meeting the OSDF waste acceptance criteria (WAC).

If you have any questions, please do not hesitate to contact the undersigned.

Sincerely,

Kwasi Badu-Tweneboah, Ph.D., P.E.
Project Manager/Engineer-of-Record
Ohio P.E. No. E-55354

Copies to: J.D. Chiou, Fluor Fernald, Inc.
Uday Kumthekar, Fluor Fernald, Inc.
Charles C. VanArsdale, Fluor Fernald, Inc.
Mike W. Godber, Fluor Fernald, Inc.
J.F. Beech, GeoSyntec

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GEOSYNTEC CONSULTANTS

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19 November 2002

Mr. William (Bill) A. Zebick
Construction Manager
Fluor Fernald, Inc.
P.O. Box 538704
MS: 64
Cincinnati, Ohio 45253-8704

Subject: Interim Construction Certification
Phase IV Cells 4 and 5 Construction Project
On-Site Disposal Facility
Subcontract No. 95PS005028

Dear Mr. Zebick:

GeoSyntec Consultants (GeoSyntec) has provided construction quality assurance (CQA) and construction quality control (CQC) services during the Phase IV - Cells 4 and 5 construction project at the Fernald Environmental Management Project (FEMP) site. The purpose of this letter is to document that, based on the CQA and CQC activities performed by GeoSyntec, construction of the liner system within the footprint of Cell 5 is substantially complete.

GeoSyntec CQC personnel have monitored, tested, and documented installation of the soils and geosynthetics components of the Cell 5 liner system, including the prepared subgrade, compacted clay liner, granular leachate collection and detection layers, geosynthetic clay liners, geomembrane liners, geotextile cushion and filter layers, and leachate collection piping systems. Field reports, logs, geotechnical and geosynthetic testing reports, and other associated documentation have been reviewed for accuracy and completeness. GeoSyntec is in the process of completing a final certification report including CQC documentation and record drawings on the construction of the Phase IV Cells 4 and 5 construction project. The final certification report, which will include documentation on the placement of the protective layer component of the Cells 4 and 5 liner systems, as well as completion of the Cell 5/6 intercell berm, will be submitted at the end of the 2002 construction season.

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Huntington Beach, CA

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Based on our observations and documentation, the OSDF Cell 5 liner system construction has been completed in general accordance with the project specifications, drawings, CQA Plan, and approved design and/or specification changes. The construction has been in full compliance with applicable or relevant and appropriate requirements (ARARs), functional requirements, and general design requirements described in the Design Criteria Package developed and approved during the design process. On the basis of our observations and testing it is anticipated that Cell 5 is ready to begin receiving impacted material meeting the OSDF waste acceptance criteria (WAC).

If you have any questions, please do not hesitate to contact the undersigned.

Sincerely,

Kwasi Badu-Tweneboah, Ph.D., P.E.
Project Manager/Engineer-of-Record
Ohio P.E. No. E-55354

Copies to: J.D. Chiou, Fluor Fernald, Inc.
Uday Kumthekar, Fluor Fernald, Inc.
Charles C. VanArsdale, Fluor Fernald, Inc.
Mike W. Godber, Fluor Fernald, Inc.
Don Pfister, Department of Energy
J.F. Beech, GeoSyntec

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APPENDIX B

Photographic Documentation

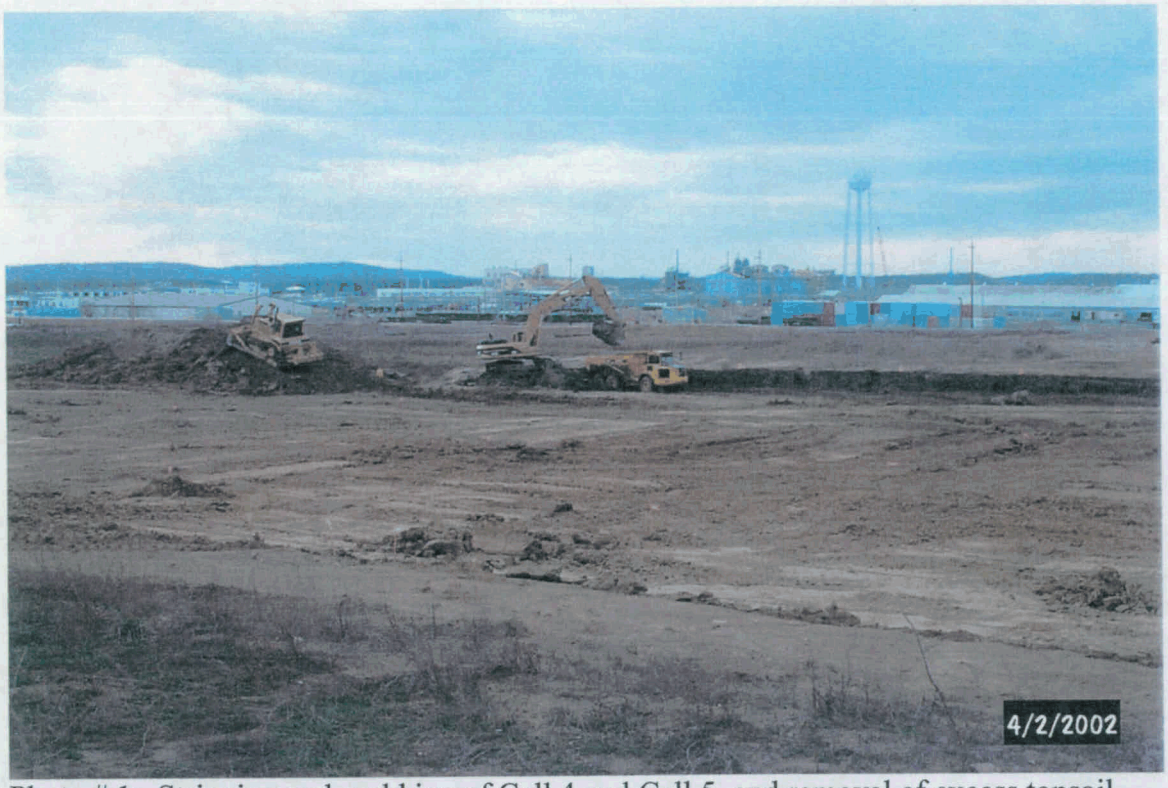

Photo # 1: Stripping and grubbing of Cell 4 and Cell 5, and removal of excess topsoil.

Photo #2: Removal of excess topsoil in Cell 4 and Cell 5.

Photo # 3: Stockpiling of the excess topsoil in future Cell 7 footprint.

Photo # 4: Preparation of subgrade in Cell 4 and Cell 5.

Photo # 5: Undercutting of soft areas in Cell 4 exposed more topsoil and perched water.

Photo # 6: Perched water was encountered during undercutting of soft areas in Cell 4.

Photo # 7: Undercutting of soft area in Cell 4 identified from proofrolling.

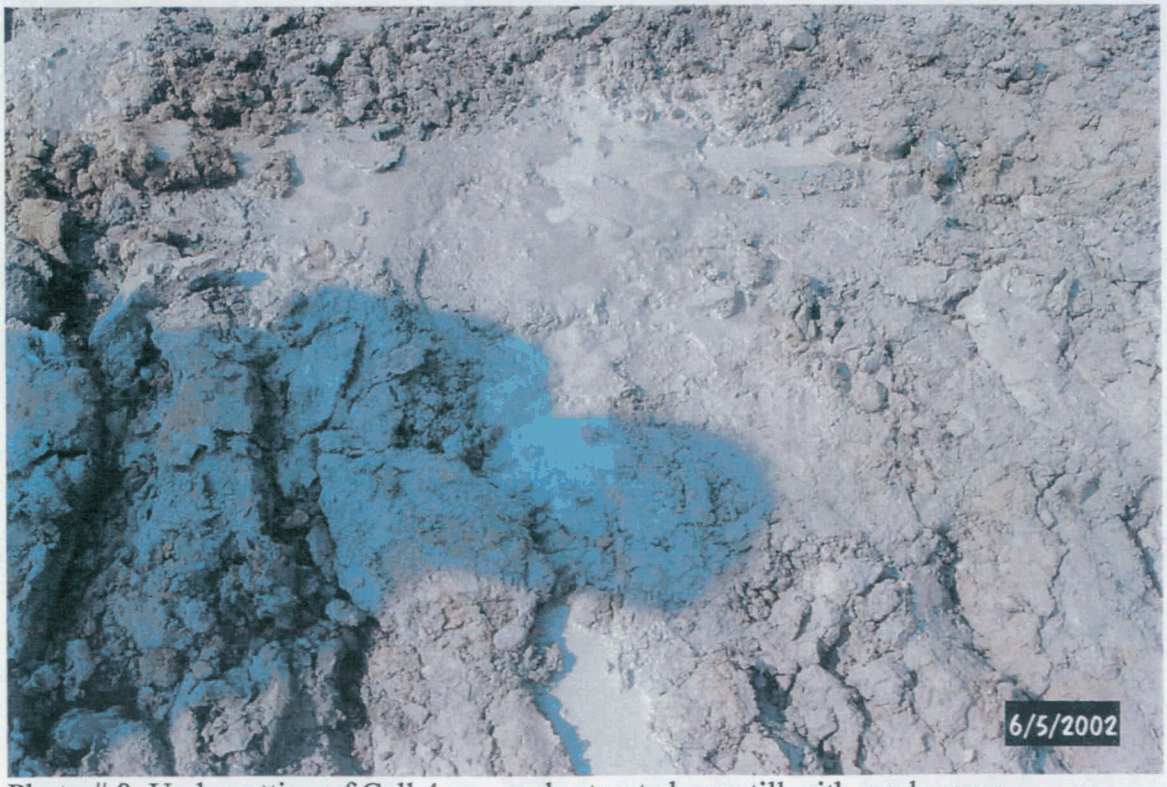

Photo # 8: Undercutting of Cell 4 exposed saturated gray till with sand seams.

Photo # 9: Geotextile and riprap were used to bridge over the soft areas in Cells 4 and 5. Brown till was then placed and compacted to subgrade design elevations.

Photo # 10: Perched water was encountered during undercutting of soft areas in Cell 5.

Photo # 11: Geotextile and riprap were used to bridge over the soft undercut areas in Cell 5.

Photo # 12: Construction of the east perimeter berm and slope for Cell 4 and Cell 5.

Photo # 13: Cell 4 subgrade preparation.

Photo # 14: Screening and processing of clay liner and cap material in the east field borrow area.

Photo # 15: The compacted clay liner was placed on the subgrade in approximately 8-inch loose lifts, moisture conditioned, scarified with the soil stabilizer, and compacted with a Caterpillar sheepsfoot.

Photo # 16: Use of the soil stabilizer to process a lift of clay liner prior to compaction.

Photo # 17: After scarification with the soil stabilizer and prior to compaction of the clay liner lift, visible oversized rock particles were removed by hand.

Photo # 18: After scarification with the soil stabilizer and moisture conditioning, the clay liner on the 4:1 slope was compacted with a Caterpillar 815 sheepsfoot compactor.

Photo # 19: After scarification with the soil stabilizer and prior to compaction of the clay liner lift, visible oversized rock particles were removed by hand.

Photo # 20: Clay liner material was processed with the soil stabilizer at the toe of the east slope and placed on the 4:1 slope with a D6 Caterpillar Bulldozer.

Photo # 21: Processing and compaction of the clay liner on the Cell 4/Cell 5 Intercell Berm.

Photo # 22: The geomembrane and GCL at the tie-in to Cell 3 were rolled back to facilitate clay liner installation.

Photo # 23: Excavation of the secondary liner anchor trench on the east perimeter of Cell 4.

Photo # 24: Sealing the surface of the compacted clay liner on the east slope of Cell 4 with a smooth drum compactor.

Photo # 25: Preparation of the compacted clay liner surface in Cell 4 prior to the installation of the overlying geosynthetics.

Photo # 26: Preparing pipe face for welding to the Cell 4 liner penetration box.

Photo # 27: Installation of liner penetration boxes in Cell 4.

Photo # 28: During removal of saturated clay liner material it was discovered that the compacted clay liner under the Cell 5 liner penetration boxes did not meet the minimum 3-ft thickness.

Photo # 29: Replacement and repair of compacted clay liner east of the Cell 5 liner penetration boxes.

Photo # 30: The GCL rolls were deployed on the compacted clay liner surface using a posi-track excavator.

Photo # 31: The 80-MIL textured HDPE geomembrane panels were oriented parallel to the maximum line of slope and overlapped 4 to 6 inches.

Photo # 32: Installation of the GCL and 80-MIL geomembrane components of the Cell 4 secondary liner.

Photo # 33: The primary liner GCL rolls were deployed on the LDS layer stone surface using a posi-track excavator.

Photo # 34: The 80-MIL textured HDPE geomembrane panels on the Cell 5/Cell 6 intercell berm were oriented parallel to the maximum line of slope and overlapped 4 to 6 inches.

Photo # 35: Adjacent geomembrane panels were welded using a double-track fusion welding machine.

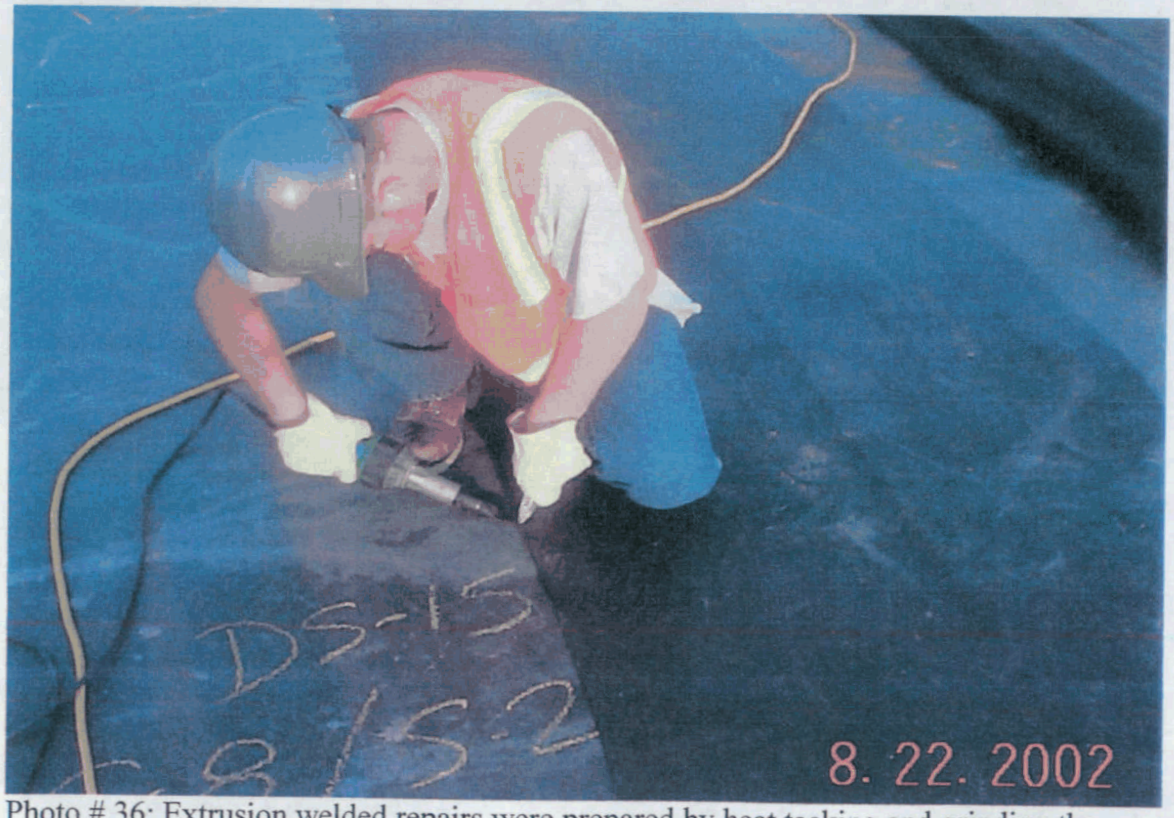

Photo # 36: Extrusion welded repairs were prepared by heat tacking and grinding the interface between panels.

Photo # 37: Extrusion welded seams and repairs were prepared by heat tacking and grinding the interface between panels.

Photo # 38: An extrusion welding machine was then used to weld the gemembrane seams and repairs.

Photo # 39: The primary geomembrane at the Cell 3/Cell 4 tie-in was prepared prior to welding the seam.

Photo # 40: A vacuum box was used to non-destructively test the extrusion welded seams and repairs.

Photo # 41: Upon completion of trial welds and destructive seam sampling, coupons were destructively tested in the field.

Photo # 42: The deployed geomembrane was rolled back to install the GCL around the Cell 4 liner penetration boxes.

Photo # 43: The geomembrane over the Cell 4 liner penetration boxes was trimmed prior to welding to the boxes.

Photo # 44: Cell 4 penetration boxes upon completion of extrusion welding the geomembrane to the tops of the liner penetration boxes.

Photo # 45: A windy storm event caused large wrinkles in the primary geomembrane liner.

Photo # 46: The geosynthetics installer pulled out the wrinkles caused by the storm with laborers and heavy equipment.

Photo # 47: The geosynthetics installer pulled out the wrinkles caused by the storm with laborers and heavy equipment.

Photo # 48: A large rain event resulted in water pooling on the Cell 4 primary geomembrane.

Photo # 49: A large rain event resulted in water pooling in the Cell 5 LDS layer # 78 stone.

Photo # 50: GCL along the Cell 3 and Cell 4 primary tie-in was hydrated after a major rain event, which was removed and repaired.

Photo # 51: GCL in Cell 4 was hydrated after a major rain event, which was removed and repaired.

Photo # 52: Hydrated primary GCL was removed from the Cell 4 drainage corridor.

Photo # 53: After hydrated primary GCL was removed in the Cell 4 drainage corridor, new GCL was installed.

Photo 54: Leak Location Services, Inc. (LLSI) used the above tools to detect leaks in the primary layer 80-MIL textured HDPE geomembrane.

Photo # 55: Leak Location Services, Inc. (LLSI) used the above tools to detect leaks in the primary layer 80-MIL textured HDPE geomembrane.

Photo # 56: The 10 oz/yd^2 geotextile panels were placed over the 80-MIL textured HDPE geomembrane, overlapped approximately 6 inches and sewn continuously.

Photo # 57: Upon completion of the geosynthetics installation in Cell 4, the anchor trench was backfilled and compacted with a walk behind vibratory sheepsfoot compactor.

Photo # 58: Upon completion of the geosynthetics installation in Cell 5, the anchor trench was backfilled and compacted with a walk behind vibratory sheepsfoot compactor.

Photo # 59: Gravity Inlet Structure (GIS # 7) on the west side of Cell 5.

Photo # 60: The # 78 stone used for the LDS layer in Cell 5 was graded to a 1-ft thickness using a Caterpillar LGP D6 Dozer.

Photo # 61: The LCS layer stone was placed over the primary geotextile cushion utilizing 3 ft. thick haul roads.

Photo # 62: The LCS layer stone was then graded to a 1 ft thickness using a Caterpillar LGP D6 Bulldozer.

Photo # 63: Geotextile was deployed over the LCS layer stone, overlapped approximately 6 inches and continuously sewn. The impacted material placement ramp is being constructed in the background.

Photo # 64: Geotextile was deployed over the LCS layer stone, overlapped approximately 6 inches and continuously sewn. The impacted material placement ramp is being constructed in the background.

Photo # 65: Upon completion of the primary liner system, an impacted materials haul road was constructed on the Cell 4/Cell 5 intercell berm.

Photo # 66: Upon completion of the primary liner system, an impacted materials haul road was constructed on the Cell 4/Cell 5 intercell berm.

Photo # 67: Upon completion of the primary liner system, the "clean" protective layer was placed on the south side of the Cell 5/Cell 6 intercell berm.

Photo # 68: Upon completion of the primary liner system, the "impacted" protective layer was placed in Cells 4 and 5.

Photo # 69: Construction of the slope drain pipe for the impacted material haul road.

Photo # 70: Installation of the Cell 6 horizontal monitoring well.

Photo # 71: Cell 6 horizontal monitoring well installation.

Photo # 72: Cell 6 horizontal monitoring well installation. Welding the perforated pipe section to the solid pipe section.

Photo # 73: Installation of the LDS, LCS, and LCSR pipes for Valve House 6.