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CONSTRUCTION QUALITY ASSURANCE

FINAL REPORT

PHASE IV - CELL 2 FINAL COVER AND PHASE V - CELL 6 LINER 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

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under

Fluor Fernald, Inc.
Contract No. 03FF0699

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February 2004
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United States Department of Energy

Fernald Closure Project
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ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highways and Transportation Officials
ACI	American Concrete Institute
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
DS & D	Demolition, Soils and Disposal
EFBA	East Field Borrow Area
EPLTS	Enhanced Permanent Leachate Transmission System
FCP	Fernald Closure Project
FCP	Fernald Environmental Management Project
FFC	Fluor Fernald Construction
GCC	Geosynthetic Clay Cap
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

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ACRONYMS AND ABBREVIATIONS

LLSI	Leak Location Services, Inc
LTS	Leachate Transmission System
MDD	Maximum Dry Density
MH	Manhole
NCR	Nonconformance Report
O & M	Operations and Maintenance
OAC	Ohio Administrative Code
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
OMC	Optimum Moisture Content
OSDF	On-Site Disposal Facility
PI	Plasticity Index
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

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1. INTRODUCTION

1.1 Terms of Reference

This final report summarizes the Construction Quality Control (CQC) and Construction Quality Assurance (CQA) activities performed by GeoSyntec Consultants (GeoSyntec) during the On-Site Disposal Facility (OSDF) Phase IV – Cell 2 final cover and Phase V – Cell 6 liner construction projects at the Fernald Closure Project (FCP) (previously known as 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 Cell 2 final cover and Cell 6 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 7 liner and Cell 3 final cover construction; (ii) tie-in of the dual-containment pipes from valve house (VH) No. 6 to Cell 6 outlet; (iii) construction of horizontal monitoring well (HMW) for future Cell 7; (iv) construction of the dual-containment pipes from the valve house (VH) No. 7 footprints to future Cell 7 outlet; (v) excavation, removal and backfilling of portions of the temporary leachate transmission system (LTS); and (vi) subgrade preparation in the footprints of future Cells 7 and 8 construction areas, including backfilling of the abandoned OSDF Sedimentation Basin No. 1 and sewage treatment plant (STP) excavation. 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 Contract 03FF0699 by Dr. Kwasi Badu-Tweneboah, P.E., Mr. Collin P. Sukow, and Mr. Timothy Willis, Jr.; and it was reviewed by Mr. David K. Phillips, P.E., all of GeoSyntec.

1.2 Background

The OSDF is a mixed low-level radioactive waste (LLRW) disposal facility dedicated to the FCP 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 FCP (or FEMP) remediation activities.

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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 June 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 sixth year (2002) of construction consisted of Cells 4 and 5 liner systems construction and placement of impacted materials in Cells 2 and 3 as part of the OSDF Phase IV project. Construction of the Cells 4 and 5 liner systems and ancillary structures occurred between April 2002 and April 2003. A CQA Final Report for the OSDF Phase IV – Cells 4 and 5 liner systems construction was prepared and issued by GeoSyntec in June 2003 [GeoSyntec, 2003]. Placement of impacted materials in Cells 2 and 3 began in April 2002, and continued with placement of impacted protective layer materials in Cells 4 and 5 in November and December 2002, respectively.

The Cell 2 final cover and Cell 6 liner systems were constructed as part of the OSDF Phase IV and Phase V projects in 2003 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 – Cell 2 final cover and Phase V – Cell 6 liner construction projects.

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 – Cell 2 final cover and Phase V – Cell 6 liner projects were 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) needle-punched 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) needle-punched nonwoven geotextile cushion layer;
- 80-mil (2.0-mm) thick textured high density polyethylene (HDPE) 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) needle-punched nonwoven geotextile cushion layer;
- 80-mil (2.0-mm) thick textured HDPE geomembrane component of a composite secondary liner (hereafter referred to as secondary liner geomembrane);
- a GCL component of the composite secondary liner;
- 3.0-ft (0.9-m) thick compacted clay liner component of the composite secondary liner; and
- varying thickness of prepared subgrade or compacted fill (hereafter referred to as subgrade).

The Cell 6 footprint has approximately 700-ft (210-m) long by 400-ft (120-m) wide rectangular configuration. Cell 6 is located immediately south of Cell 5 and is bounded by intercell berms on the north and south. Cell 6 construction also includes a temporary termination to the liner system in the future Cell 7 footprint.

The final cover system, designed to isolate impacted materials in the OSDF, includes the following components, from top to bottom (Figure 2-2):

- 6-in. (0.15-m) thick topsoil layer;
- 1.75-ft (0.425-m) thick vegetative soil layer;
- 6-in. (0.15-m) thick granular filter layer;
- 3-ft (0.9-m) thick biointrusion barrier with choke stone layer;
- 1-ft (0.3-m) thick cover drainage layer;
- 8-oz/yd^2 (270-g/m^2) needle-punched nonwoven geotextile cushion layer;
- 80-mil (2.0-mm) thick textured HDPE geomembrane component of the composite cap;
- a geosynthetic clay cap (GCC) component of the composite cap;
- 2-ft (0.6-m) thick compacted clay cap component of the composite cap; and
- 1-ft (0.3-m) thick non-impacted contouring layer.

The Cell 2 final cover system footprint covers an area of approximately 9 acres (3.6 hectares); and is bounded on the north by the Cell 1 final cover system, to the west and east by the perimeter drainage channels, and on the south by the temporary termination area for future Cell 3 final cover construction.

The Certified-For-Construction (CFC) Drawings and Technical Specifications for the OSDF Phase IV and Phase V constructions 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 – Cell 2 final cover and Phase V – Cell 6 liner projects was Fluor Fernald Construction (FFC) under the self-performance program for the closure of the FCP [Fluor Fernald, 2002]. Installation of the geosynthetics components of the Cell 1 final cover and Cell 6 liner systems was performed by The Istre Company (TIC) of Glenpool, Oklahoma, as a subcontractor to FFC. Leak detection testing of the installed Cell 2 final cover geomembrane and Cell 6 primary liner geomembrane was performed by Leak Location Services, Inc. (LLSI) of San Antonio, Texas, as subcontractor to FFC. The HDPE pipes for the Cell 6 liner system and tie-in of the LDS, LCS, and RLCS dual-containment pipes to the Cell 6 outlet, Cell 7 HMW, and partial installation of the dual-containment piping system from the VH-7 footprint to Cell 7 outlet were installed by Wise

Construction Company (Wise) of Cincinnati, Ohio as subcontractor to FFC. Closed-circuit television (CCT) surveys of the Cell 6 LDS, LCS, and RLCS carrier pipes from the valve house were performed by Water Workes, Inc. of Dayton, Ohio, as subcontractor to FFC. The surveyor retained by Fluor Fernald for the OSDF Phase IV – Cell 2 final cover and Phase V – Cell 6 liner system construction projects was Tecumseh Surveying Inc. (Tecumseh) of Shandon, 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 – Cell 2 final cover and Phase V – Cell 6 liner construction projects is included in Section 3.2 of this report.

As required by the project specifications, Tecumseh surveyed the required layers of the: (i) Cell 2 final cover system (i.e., perimeter subgrade, top of contouring layer, top of compacted clay cap, layout of geomembrane cap, top of cover drainage layer, top of biointrusion barrier layer, top of granular filter layer, top of vegetative soil layer, and the top of topsoil layer); and (ii) Cell 6 liner system (i.e., subgrade, top of compacted clay liner, 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). Tecumseh prepared the as-built drawings for the subgrade and top of each soil component as well as geomembrane panel layouts of the Cell 2 final cover and Cell 6 liner systems.

Primary construction activities monitored by GeoSyntec's CQA personnel for the OSDF Phase IV - Cell 2 final cover construction project included the following:

- rough grading of the subgrade in the perimeter (i.e., cut and fill operations);
- placement of compacted fill material in fill areas along the perimeter subgrade and southern temporary termination area of the Cell 2 final cover;
- preparation of the surface of the select impacted material layer for placement of the contouring layer;
- construction of the contouring layer;
- construction of the compacted clay cap;
- installation of the geosynthetic clay cap;
- installation of the geomembrane cap;
- installation of the geotextile cushion layers;

- placement of the cover drainage layer;
- placement of the biointrusion barrier with choke stone layer;
- placement of the granular filter layer;
- construction of the vegetative soil layer;
- placement of the topsoil layer;
- seeding and installation of the erosion mat over the final cover;
- construction of the monitoring access; and
- construction of the perimeter drainage channels along the limits of the Cell 2 final cover.

Primary construction activities monitored by GeoSyntec's CQA personnel for the OSDF Phase V Cell 6 liner project included the following:

- rough grading of the cell floor (i.e., cut and fill operations);
- final preparation of the subgrade in excavation areas;
- placement of compacted fill material in fill areas;
- construction of the perimeter and intercell berms;
- construction of the compacted clay liner and 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 geomembrane;
- 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 Cell 6 liner system, Cell 7 HMW, and installation of the dual-containment pipes for Cell 7 included the following:

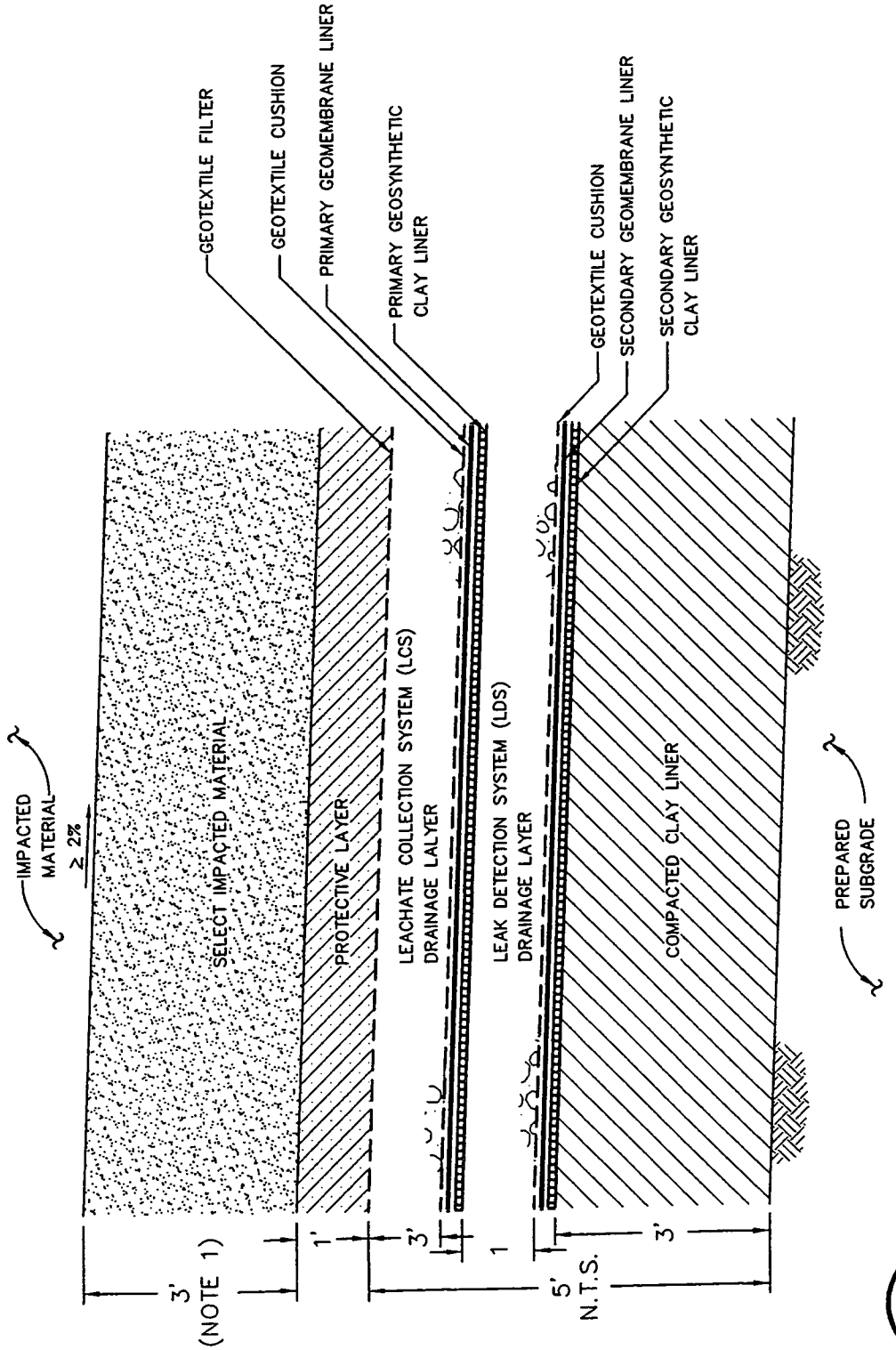
- trenching and excavation for the HDPE piping systems;
- placement and compaction of embedment fill for pipes;
- installation and welding of HDPE piping systems, including the Cell 7 HMW and partial installation of the dual-containment pipe extensions from VH-7 footprint to Cell 7 outlet;
- hydrostatic and/or pneumatic testing of the HDPE piping systems;
- CCT surveys and inspections of the LDS, LCS, and RLCS carrier pipes from VH-6 to Cell 6; and
- backfilling and grading of the construction area.

The approval process for construction materials used during the OSDF Phase IV – Cell 2 final cover and Phase V – Cell 6 liner construction projects 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 and other construction materials. 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 – Cell 2 final cover construction began on 14 April 2003 with the placement of the first lift of the non-impacted contouring layer. Placement and compaction of the first lift of the compacted clay cap began on 12 May 2003. TIC began and completed installation of the geosynthetics for the Cell 2 final cover system on 22 June 2003 and 17 July 2003, respectively. LLSI performed leak detection testing of the installed geomembrane cap from 14 July 2003 through 17 July 2003. The construction of the OSDF Phase IV – Cell 2 final cover system was substantially completed on 12 October 2003, prior to beginning seeding and installation of the erosion mat. Seeding of the final cover was completed on 29 October_2003, and the installation of the erosion mat was completed on 12 November 2003.

Earthwork associated with OSDF Phase V – Cell 6 liner system construction began on 16 March 2003. FFC began and completed construction of the Cell 6 compacted clay liner (including the protective clay wedge) on 29 May and 7 August 2003, respectively. TIC began and completed installation of the secondary liner geomembrane on 17 July 2003 and 8 August 2003, respectively. TIC began and completed installation of the primary liner geomembrane on 12 August and 18 September 2003, respectively. LLSI began and completed leak detection testing of the installed primary liner geomembrane on 10 September and 24 September 2003, respectively. The construction of the OSDF Phase V – Cell 6 liner system was substantially completed on 31 October 2003, prior to beginning placement of protective layer material meeting the requirements of the Impacted Material Placement (IMP) Plan. Protective layer placement began on 18 November 2003 and was completed on 22 November 2003.

Earthwork associated with the installation of the HDPE piping system for Cell 7 began on 17 November 2003 and was partially completed at the time of this report preparation.



NOTE

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

SECTION

CROSS SECTION OF LINER SYSTEM ON-SITE DISPOSAL FACILITY

SCALE: N.T.S.
XREF: F04F002.DWG

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	2-1
PROJECT NO.	GQ3211-01
DOCUMENT NO.	F030002.CDG
FILE NO.	F04F002

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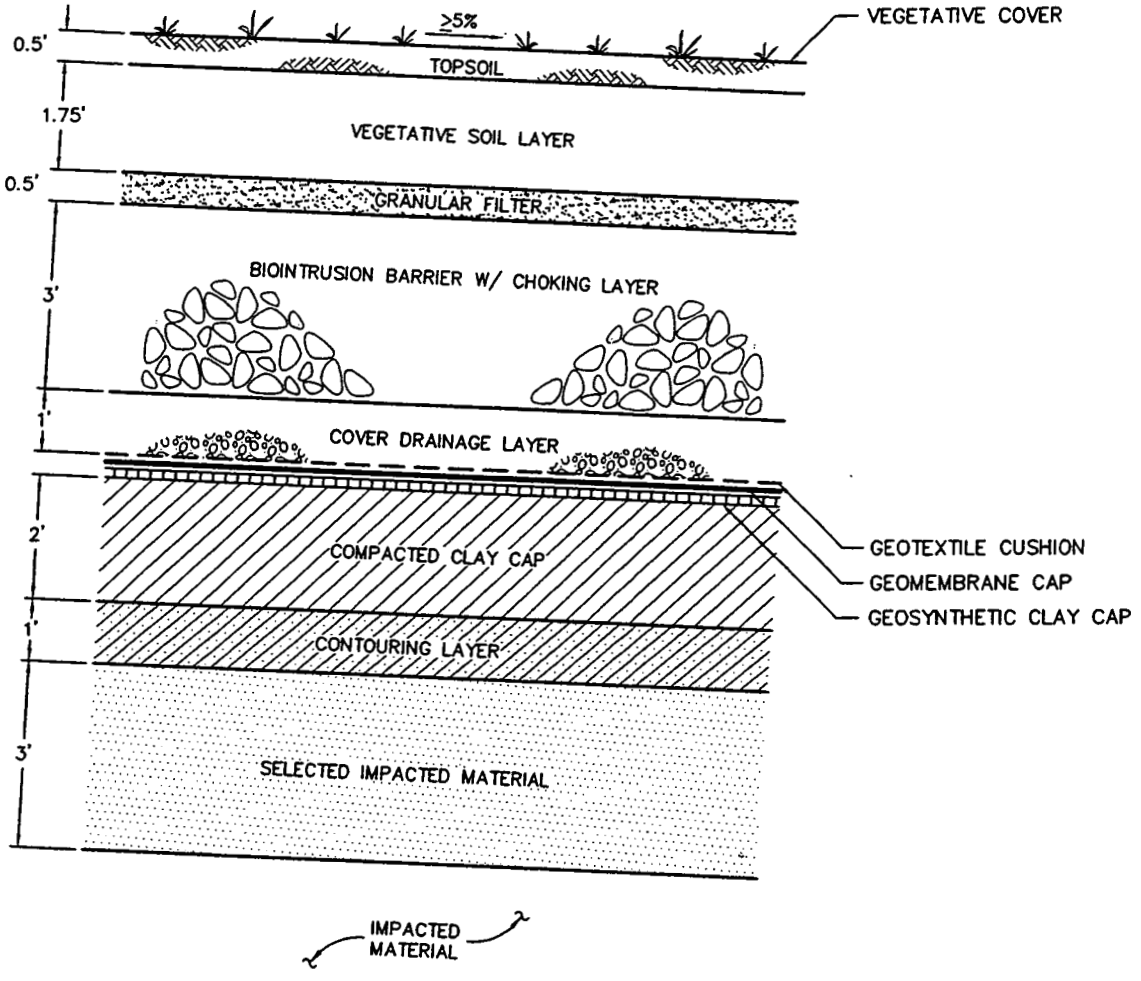
CROSS SECTION OF FINAL COVER SYSTEM ON-SITE DISPOSAL FACILITY



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GEOSYNTEC CONSULTANTS ATLANTA, GEORGIA	FIGURE NO.	2-2
	PROJECT NO.	GQ3211-01
	DOCUMENT NO.	F030002.CDG
	FILE NO.	F04F001.DWG

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 – Cell 2 final cover and Phase V – Cell 6 liner projects 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 – Cell 2 final cover and Phase V – Cell 6 liner constructions. 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, prepared by GeoSyntec Consultants, dated March 2002;
- "*Procurement Specifications, On-Site Disposal Facility Procurement Specifications*", Revision 0, prepared by GeoSyntec Consultants, dated October 2001,;
- "*Construction Quality Assurance Plan, On-Site Disposal Facility*", 20100-PL-0006, Revision 1, prepared by GeoSyntec Consultants, dated May 2001;
- "*On-Site Disposal Facility – Phase IV Certified-For-Construction Drawings*", Revision 0, prepared by GeoSyntec Consultants, dated August 2001;
- "*On-Site Disposal Facility – Phase V Certified-For-Construction Drawings*", Revision 0, prepared by GeoSyntec Consultants, dated January 2002; and
- "*Impacted Materials Placement Plan, On-Site Disposal Facility*", 20100-PL-007, Revision 3, prepared by GeoSyntec Consultants, dated August 2001.

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 Cell 6 liner and Cell 2 final cover 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 the Cell 2 perimeter and Cell 6 subgrade;
- monitoring placement and compaction of compacted fill in subgrade areas requiring backfill;
- monitoring placement and compaction of contouring layer for the Cell 2 final cover;

- monitoring final preparation and proof rolling of top of Cell 2 contouring layer and Cell 6 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 6 floor;
- monitoring final preparation of the Cell 6 floor subgrade;
- monitoring placement and compaction of clay cap for Cell 2 and clay liner and perimeter berm for Cell 6;
- testing of the in-place moisture/density of the compacted fill and compacted clay liner and cap;
- monitoring surface of compacted clay liner and cap for desiccation cracks prior to deployment of overlying secondary liner GCL and GCC;
- monitoring placement and tracking of cover drainage layer, leachate collection and leak detection systems, biointrusion barrier with choke stone layer, and granular filter;
- monitoring placement and compaction of vegetative soil and topsoil layers;
- 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;
- periodically monitoring placement of riprap in the perimeter drainage channels;
- periodically monitoring placement and compaction of road base aggregate materials for the monitoring access along the eastern perimeter of Cell 2 final cover;
- monitoring placement of backfill in the Cell 6 perimeter anchor trench;
- monitoring placement and compaction of protective clay layer (i.e., clay wedge) above the anchor trenches and on the east and west perimeter berms;
- periodically monitoring placement and compaction of non-impacted protective soil material in the southern temporary termination area of Cell 2 final cover and on the southern part of the Cell 6 and Cell 7 intercell berm;

- monitoring placement and tracking of impacted protective layer in Cell 6;
- periodically monitoring trenching operations for installation of HDPES;
- periodically monitoring placement and compaction of embedment fill and trench backfill around pipes; and
- testing of in-place moisture/density of the compacted trench backfill.

Geosynthetics:

- tracking the inventory of geosynthetics materials (i.e., GCL and GCC, 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 (at the manufacturing plants) 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 and GCC panels;
- monitoring placement of granular bentonite between overlapping GCL and 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 Cell 2 final cover and Cell 6 primary liner geomembrane;
- reviewing and commenting on the geomembrane panel layout drawings prepared by Tecumseh;
- monitoring the installation of geotextile and continuous sewing of adjacent panels;
- periodically monitoring the installation and stapling of erosion mat on the completed portions of the Cell 2 final cover;
- 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 Systems (LDS and LCS):

- 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 geomembrane;
- reviewing source qualification test results on samples of aggregate used in the LDS and LCS layer systems;
- monitoring placement of the aggregate for the LDS and LCS layers;
- monitoring installation of the LCS collection pipe, redundant LCS collection pipe, LDS collection pipe, and LDS and LCS drainage corridor aggregate;
- monitoring joining of the perforated sections of the HDPE pipes to the solid-wall sections of the HDPE pipes from Cell 6 outlet; and

- monitoring of closed-circuit television (CCT) surveys of the LDS, LCS, and RLCS carrier pipes from VH-6 into Cell 6.

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 tie-in of the LDS, LCS, and RLCS pipes and Cell 7 HMW, and the simultaneous butt-fusion welding for the installation of the dual-containment pipes from Cell 7 outlet to VH-7 footprint; and
- visual monitoring of the hydrostatic pressure and pneumatic testing of the dual-containment piping system tie-in from VH-6 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 – Cell 2 final cover and Phase V – Cell 6 liner projects, an interim construction certification letter (for the Cell 6 liner only) was prepared and submitted to Fluor Fernald. A copy of the letter is included in Appendix A. This final documentation report includes all construction required by the Project Documents except seeding of completed Cell 6 perimeter berm slopes, and the completion of the installation of the piping systems for Cell 7 (i.e. HMW, LDS, LCS, and RLCS pipes from VH-7 footprint to Cell 7 outlet).

Items that were completed during the Phase IV and Phase V construction projects 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 3 final cover and Cell 7 liner constructions;

- subgrade preparation work for Cells 7 and 8, including construction of the Cell 7 east perimeter berm and backfilling of the abandoned sewage treatment plant excavations; and

- other miscellaneous construction work performed by FFC and/or its subcontractors during the 2003-2004 construction projects.

The conformance test results, installation of the Cell 7 piping systems, and compacted fill placement and testing data 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 GeoSyntec for review; these documents are included in the appendices to this final report.

Progress survey data were provided to GeoSyntec for review. The licensed surveyor (Tecumseh) prepared as-built drawings for the top of each soil layer in the liner system. Tecumseh 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 H; Volume VI contains Appendices I through U. A summary of the documentation included in the appendices to the final report is provided below:

- Appendix A: Cell 6 Interim Construction Certification Letter

- Appendix B: Photographic Documentation

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- Appendix C: Weekly Field Reports, Minutes of Meetings, and Correspondence
- Appendix D: Personnel Logs
- Appendix E: Geotechnical Laboratory Test Results
- Appendix F: Manufacturers'/Suppliers' 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 Surface
- 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 Reports
- 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)

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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)
- Allan Harris, DOE QA/QC Representative
- Donald A. Pfister, P.E., DOE Fernald Facility Representative
- Johnny W. Reising, DOE Representative

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

Fluor Fernald, Inc. (Owner's Representative and Prime Contractor)
- Thomas M. Beasley, OSDF Construction Manager
- H. Pete Bolig, Safety & Health Representative
- Charles E. Carney, Soil Construction Manager
- Thomas D. Carr, Construction Coordinator
- J.D. Chiou, Ph.D., P.E., SDF Project Manager
- Jeffrey R. Ellis, P.E., OSDF Construction Engineer
- Corey Fabricante, Radiological Control Team Leader
- Frank L. Flack, Construction Contracts Manager
- Reinhard Friske, Quality Assurance Team Leader
- Donald B. Goetz, Construction Engineer
- Kevin S. Harbin, Construction Superintendent
- Alan Hohnhorst, Contracts and Acquisition
- D. Warren Hooper, SDFP Senior Construction Manager
- Gregg K. Johnson, Safety & Health Team Leader
- Uday A. Kumthekar, P.E., Engineering Manager
- Surinder Kumar, P.E., Engineer
- Jeffrey A. Middaugh, Safety & Health Representative
- Janet K. Porter, SDFP Secretary
- Dan Powell, DS&D Project Director
- 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. Allen, Quality Assurance
- Jerry Williams, Construction Superintendent
- Eric Woods, Natural Resources/Stewardship Manager
- William A. Zebick, SDFP Construction Support Manager

GeoSyntec Consultants (CQA Consultant)
- Sheila Abney, Administrative Assistant
- Kwasi Badu-Tweneboah, Ph.D., P.E., Resident Engineer
- R. Neil Davies, P.E., Principal in Charge
- David Evans, Engineering Technician
- Brian Habermehl, Engineering Technician
- Rick Hastie, Senior Engineering Technician
- Ken Herrick, Engineering Technician
- David K. Phillips, P.E., Project Manager
- Steven Schaeffer, Engineering Technician
- Collin P. Sukow, CQA Site Manager
- Christopher Walker, Senior Engineering Technician
- Timothy Willis, Safety & Health Representative
- 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
- 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

Tecumseh Surveying, Inc. (Contractor's Surveyor)
- Lynn E. Hirsch, P.L.S., Senior Professional Land Surveyor

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., Resident Engineer	01 April 2003 – Present
• C.P. Sukow, CQA Site Manager	01 April 2003 – Present
• David Evans, Engineering Technician	01 April 2003 – 19 September 2003
• Ken Sparks, Senior Engineering Technician	01 April 2003 - 23 May 2003
• T. Byran York, E.I.T., Senior Engineering Technician	03 April 2003 – 15 May 2003
• Christopher Walker, Senior Engineering Technician	01 April 2003 - 30 April 2003 12 May 2003 - 06 September 2003 24 September 2003 - Present
• Tim Willis, Senior Engineering Technician	29 April 2003 - Present
• Rick Hastie, Engineering Technician	09 June 2003 - 31 October 2003
• Brian Habermehl, Engineering Technician	19 May 2003 - Present
• Steven Schaeffer, Engineering Technician	09 June 2003 - Present
• Ken Herrick, Engineering Technician	07 May 2003 - 22 August 2003
• Sheila Abney, Administrative Assistant	01 April 2003 - Present
• Nelson Breedon, Construction Manager	20 May 2003 - 22 May 2003
• Dave Phillips, P.E., Project Manager	05 May 2003 - 06 May 2003 25 July 2003 - 26 July 2003

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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 – Cell 2 final cover and Phase V – Cell 6 liner projects. 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 – Cell 2 final cover and Phase V – Cell 6 liner construction projects, are included in Appendix C.

Results of CQA monitoring, testing, and documentation performed by CQA personnel during the OSDF Cell 2 final cover and Cell 6 liner constructions 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 Cell 2 final cover and Cell 6 liner, RCIs and DCNs that provided design changes and clarifications to the CFC Drawings and Specifications were processed and approved according to procedures described in FCP 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 – Cell 2 final cover and Phase V – Cell 6 liner construction projects 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 – Cell 2 final cover and Phase V – Cell 6 liner construction projects. The components of the projects completed during the construction period consisted of Cell 2 final cover and Cell 6 liner system constructions; tie-in of the dual-containment pipes from valve house (VH) No. 6 to Cell 6 outlet; excavation, removal and backfilling of portions of the temporary LTS; subgrade preparation in the footprints of future Cells 7 and 8 construction areas, including backfilling of the abandoned OSDF Sedimentation Basin No. 1 and sewage treatment plant excavation; and excavation, screening of clay liner and cap material, and interim restoration of the EFBA Sub-areas 3, 4, 5, and 6. Different earthwork materials were used to construct the various components of the project. These materials included existing subgrade material, compacted fill, contouring layer, compacted clay liner and cap, cover drainage layer, LDS and LCS drainage layers, LDS and LCS drainage corridors, biointrusion barrier and choke stone materials, granular filter, vegetative soil layer, topsoil, road base aggregate, riprap, and pipe embedment fill material. The earthwork construction activities using these materials are generally described below.

Cell 2 Final Cover:

- Repairs were made to the select impacted material layer that was damaged from erosion. Fill material proposed for the contouring layer were used to repair the eroded surface of the select impacted material layer. A low ground pressure (LGP) bulldozer was used for placement, compaction and grading of the soil to complete the erosion repairs.

- The surface of the Cell 2 select impacted material layer was scarified by tracking with a bulldozer. Contouring layer material was placed and compacted in lifts to the design grades. The contouring layer material consisted of compacted fill, which was obtained from designated stockpiles or other borrow sources within the construction area. The contouring layer was placed in approximately 7- to 10-in. (180- to 250-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 material was compacted at 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 top of the contouring layer was proof rolled by using a loaded articulated dump truck and visually monitored by CQA personnel. Isolated areas of soft or loose materials were either dried and compacted or undercut and replaced with contouring layer material, which was compacted as described above.

- The 2-ft (0.6-m) thick compacted clay cap for the Cell 2 final cover system 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 cap 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 cap 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 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 cap 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 cover drainage layer, which varied in thickness from 1 ft (0.3 m) on the Cell 2 final cover to 2 ft (0.6 m) along the perimeter, was constructed using material obtained from off-site borrow sources. The cover drainage layer material was approved through conformance testing of samples and review of supplier's certification test results. The material was placed and compacted 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 3-ft (0.9-m) thick biointrusion barrier and choke stone layer was constructed using materials obtained from off-site borrow sources. The biointrusion barrier material was placed in lifts and the final surface was choked with the choke

stone material. The biointrusion barrier and choke stone materials were approved through conformance testing of samples and review of supplier's certification test results.

- The 6-in. (150-mm) thick granular filter layer was constructed using material obtained from off-site borrow sources; the material was approved through conformance testing of samples and review of supplier's certification test results. The granular filter layer was placed in one loose lift and compacted with a LGP bulldozer.

- The vegetative soil layer was constructed to the design grades using 7- to 9-in. (175- to 225-mm) thick loose lifts. Each lift was compacted to a minimum degree of compaction of 92 percent of the maximum dry unit weight and at moisture contents between –4 to +4 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). The vegetative soil layer material consisted of fill material, which was obtained from designated stockpiles within the construction area and from the brown-gray till in the EFBA. Fill materials used for the vegetative soil layer construction were approved through conformance testing of samples in accordance with the requirements of the Project Documents.

- The 6-in. (150-mm) thick topsoil layer was constructed using material obtained from designated stockpiles within the construction area. Topsoil material was approved through conformance testing of samples in accordance with the requirements of the Project Documents. The topsoil layer was placed in one loose lift and compacted with a LGP bulldozer.

- Base aggregate material was used to construct the monitoring access as shown on the CFC Drawings. The material was obtained from off-site borrow sources, and was approved through review of supplier's 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, placed around the final cover/monitoring access interface, and also used for temporary slope protection and other surface-water management and erosion control (SWMEC) measures. The riprap material (Type C Dumped Rock Fill) was obtained from off-site borrow sources, and was approved through review of suppliers' certification test results. The riprap material was placed in accordance with the requirements of the Technical Specifications and as shown on the CFC Drawings.

Cell 6 Liner:

- Cell 6 footprint was stripped of topsoil and additional topsoil encountered below proposed subgrade elevations. The stripped topsoil was removed, hauled, and stockpiled in the future Cell 8 footprint area.

- Cell 6 subgrade was initially rough graded. The subgrade surface was proof rolled 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 Cell 6, and compacted fill was placed and compacted to subgrade design elevations, as described below.

- The cell floor was graded to achieve the required subgrade elevations. The subgrade in areas of the cell floor that required filling were proof rolled 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 (ASTM D 698). The fill material was compacted at moisture content between 3 percent dry and 3 percent wet of the OMC measured in the standard Proctor compaction test (ASTM D 698).

- The Cell 6 perimeter berm was also constructed using compacted fill. The fill was placed in approximately 8-in. (200-mm) thick (maximum) loose lifts and compacted as described above.

- The 3-ft (0.9-m) thick compacted clay liner for Cell 6 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. The Cell 6 compacted clay liner was compacted and tested using the same procedures and methods for the Cell 2 final cover compacted clay cap, which has been described previously.

- The granular components of the Cell 6 liner system, which included a 1-ft (0.3-m) thick LDS layer and a 1-ft (0.3-m) thick LCS layer were constructed using material obtained from off-site borrow sources. 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). 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 Cell 6 footprint was constructed using impacted material obtained from the Soils Disposal Facility Project (SDFP) excavations and stockpiles. In the impacted runoff catchment area, however, non-impacted granular material meeting the requirements of the LCS drainage layer material was used to construct the 1-ft (0.3-m) thick protective layer. Non-impacted clayey soil, obtained from borrow area and excavations in Cells 7 and 8 footprint areas, was also used to construct the protective layer on the outside slopes of the Cell 6/Cell 7 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 ODOT Specifications, to meet the requirements of the Technical Specifications and as shown on the CFC Drawings.

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 FCP 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 – Cell 2 final cover and Phase V – Cell 6 liner projects are presented in Appendices S and T, respectively.

5.3 Pre-Conformance Testing Activities

A comprehensive pre-conformance sampling and testing program was conducted in the EFBA in 2000 and 2001. The purpose of the program was to identify candidate materials suitable for screening and processing as clay liner and cap material for cell liner and final cover construction. The results of the pre-conformance sampling and testing program are presented in previous OSDF CQA final reports [GeoSyntec, 2002 and 2003]. These results were used as the basis for the screening and processing of clay liner and cap material needed for the Cell 2 final cover and Cell 6 liner constructions described in this CQA final report.

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 cap, and granular drainage layer materials from the appropriate source depending on the material type.

Fill material, used in Cell 2 final cover and Cell 6 liner construction for the contouring layer, vegetative soil layer, compacted fill, and non-impacted protective layer was obtained from OSDF cell excavations, designated stockpiles within the OSDF construction areas, and from the brown-gray till within the EFBA. Compacted clay liner and cap material was obtained from the screened clay material stockpiles in the EFBA.

The granular drainage materials were obtained from off-site sources. The cover, LCS, and LDS granular drainage material (No. 78 coarse aggregate) was obtained from Martin Marietta Aggregates (Martin Marietta) quarry in Lynchburg,

Ohio. The LDS and LCS drainage corridor material (No. 57 washed gravel) was obtained from Welch Sand and Gravel, Inc. (Welch) quarry in Ross,. Ohio. The biointrusion barrier layer material (ODOT Type D Dumped Rock Fill) was obtained from the Hanson Aggregates Davon, Inc. (Hanson) Highland quarry and Eagle quarry located in Winchester and Hillsboro, Ohio, respectively. The biointrusion choke stone material (AASHTO No. 57 crushed aggregate) was obtained from the Martin Marietta quarry in Lynchburg, Ohio. The granular filter material (ODOT Type A-3 Sand) was obtained from the Welch quarry in Ross, Ohio.

The base aggregate material (ODOT No. 304 aggregate) was obtained from the Welch quarry in Ross, Ohio. The Type C riprap material, used for channel lining and other SWMEC measures, was obtained from Hanson's Eagle Quarry in Winchester, Ohio.

5.4.2 Test Methods

The following geotechnical tests, when appropriate, were performed on each of the soil components of the Cell 2 final cover and Cell 6 liner systems:

- Moisture content tests were performed on samples of compacted fill, contouring layer, vegetative soil layer, non-impacted protective layer, and compacted clay liner and cap 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, contouring layer, non-impacted protective layer, and compacted clay liner and cap. The tests (sieve analysis and hydrometer) 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, contouring layer, vegetative soil layer, and compacted clay liner and cap. The tests were performed in general accordance with ASTM D 698. Modified Proctor compaction tests were also performed on the clay liner and cap 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 liner and cap stockpile.

- Hydraulic conductivity tests were performed on the compacted clay liner and cap material. Tests were conducted on remolded individual and composite

samples of screened clay liner and cap 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 in general accordance with ASTM D 2974.

- Particle-size distribution tests were performed on samples of the coarse-grained soils used for the cover, LCS, and LDS drainage layers, the LDS and LCS drainage corridors, granular filter, and biointrusion choke stone 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 cover, LDS and LCS drainage layer and LDS and LCS drainage corridor materials. The tests were performed in general accordance with ASTM D 3042 and ASTM D 2434, respectively.

- Bulk specific gravity and absorption tests were conducted on the biointrusion barrier and choke stone materials in general accordance with ASTM C 127.

The results of the geotechnical laboratory tests performed on the soil materials used for the Phase IV – Cell 2 final cover and Phase V – Cell 6 construction projects 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 14 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 14 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 solid pipes that were installed as part of this project.

5.4.3.2 Contouring Layer

A total of 3 index tests (i.e., moisture content, particle-size distribution, Atterberg limits and classification tests) were performed on fill material used for the contouring layer and non-impacted protective layer. The material 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 4.0 in. (100 mm). A total of 3 standard Proctor compaction tests were performed on fill materials used as compacted fill and for the contouring layer.

Table 5-2 presents a summary of the geotechnical tests conducted on the fill materials used for the contouring layer. This fill material was also used for the protective layer in the Cell 6/Cell 7 intercell berm and in the temporary termination of the Cell 2 final cover.

5.4.3.3 Compacted Clay Liner and Cap

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 and cap construction. A total of 13 screened clay material stockpiles, with in-place volumes (ICY) ranging from approximately 1,520 to 9,630 yd^3 (1,160 to 7,360 m^3), were used for the Cells 2 final cover and 6 liner (including the protective clay wedge) constructions. The screened clay material stockpiles were designated and labeled as Stockpiles 02-4, 02-5, and 02-7 through 02-17 in the EFBA. Stockpiles 98-11 and 98-13 were screened clay stockpiles used originally for the construction of the Cell 2 clay wedge. The sacrificial layer of the Cell 2 clay wedge was stripped off, re-stabilized, and moisture conditioned. This material was then applied to the Cell 2 clay cap. 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 and cap material. A total of 75 index tests were performed on the compacted clay liner and cap 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 and cap material, according to the USCS.

A total of 75 standard Proctor compaction tests and 40 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 and cap material, in accordance with the CQA Plan and Technical Specifications. A total of 17 remolded hydraulic conductivity tests were performed on 13 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 and cap material stockpiles, including the established APZ for each stockpile, are presented in Appendix E. A summary of compacted clay liner and cap properties is presented in Table 5-3, which indicates that the clay liner and cap material meets the requirements of the Project Documents.

5.4.3.4 Granular Drainage Layer Materials

On-site laboratory particle-size distribution tests were performed on 19 samples obtained from the on-site stockpile for the cover, LDS and LCS 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 granular materials for the cover, LDS and LCS drainage layers. A summary of the testing requirements for the granular drainage layer materials is presented in Table 5-4.

Based on the testing performed, the granular drainage materials used in construction of the cover, LDS and LCS 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 stone; had a carbonate content of less than or equal to 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 results of the laboratory tests on the cover, LDS and LCS drainage layer materials are presented in Appendix E.

5.4.3.5 Granular Drainage Corridor Material

Five (5) particle-size distribution tests (ASTM C 136), two (2) carbonate content tests (ASTM D 3042 modified with a pH of 4), and two (2) hydraulic conductivity tests (ASTM D 2434) were conducted on the LDS and LCS drainage corridor material for the Cell 6 liner. Test results are presented in Appendix E, and summarized in Table 5-5.

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.

5.4.3.6 Biointrusion Barrier and Choke Stone

The biointrusion barrier material was tested and certified by the supplier (Hanson) and met the requirements of Type D Dumped Rock Fill, as required by the Project Documents. Additionally, a total of six (6) bulk specific gravity and absorption tests were conducted on the biointrusion barrier material to comply with the conformance testing requirements of the Project Documents. The results of the tests on the biointrusion barrier material are presented in Appendix E and summarized in Table 5-6.

The biointrusion barrier choke stone material was tested and certified by the supplier (Martin Marietta) to meet the requirements of AASHTO No. 57 crushed aggregate. Three (3) particle-size distribution tests (ASTM C 136), and one (1) bulk specific gravity test (ASTM C 127) and one (1) absorption test (ASTM C 127) were also conducted on the biointrusion barrier choke stone. Test results are presented in Appendix E, and summarized in Table 5-7.

The choke stone material used in construction of the biointrusion barrier layer classified as GW or GP according to the USCS when evaluated in accordance with ASTM D 2487; had 100 percent passing a 1.5 in. (38 mm) opening sieve when tested in accordance with ASTM C 136; generally met gradation requirements for AASHTO No. 57 stone; had a minimum bulk specific gravity of 2.60 when tested in accordance with ASTM C 127; and a maximum absorption of 2 percent when evaluated in accordance with ASTM C 127.

5.4.3.7 Granular Filter Layer

A total of five (5) index tests (particle-size distribution and classification tests) were performed on the granular filter layer material used for the Cell 2 final cover construction. The same material was also used as pipe embedment fill for the HMW and dual-containment piping systems. The material classified as SP according to the USCS and met the requirements of the Project Documents. Test results are presented in Appendix E and summarized in Table 5-8.

5.4.3.8 Vegetative Soil Layer

A total of seven (7) index tests (i.e., moisture content, particle-size distribution, Atterberg limits and classification tests) were performed on vegetative soil layer material used for the Cell 2 final cover construction. The material classified as GC, SC, or CL according to the USCS (ASTM D 2487) and the maximum particle size was 4.0 in. (100 mm). A total of seven (7) standard Proctor compaction tests were performed on fill materials used as vegetative soil layer. Table 5-9 presents a summary of the geotechnical tests conducted on the fill materials used as vegetative soil layer. Test results are presented in Appendix E.

5.4.3.9 Topsoil

A total of two (2) index tests and organic content tests were performed on samples of the topsoil used for construction of the Cell 2 final cover. Test results are summarized in Table 5-10, which indicate that the topsoil had a minimum organic content of 2 percent when tested in accordance with ASTM D 2974. Test results are presented in Appendix E.

5.5 Cell 2 Final Cover 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 CM for review and correction.

5.5.2 Repairs to Select Impacted Material Layer

CQA personnel monitored repairs to the erosion damage to the select impacted material layer. Fill material proposed for the contouring layer were used to repair the

eroded surface of the select impacted material layer. A low ground pressure (LGP) bulldozer was used for placement, compaction and grading of the soil to complete the erosion repairs. The surface of the select impacted material layer was then scarified by tracking with the LGP bulldozer prior to placement of the contouring layer.

5.5.3 Contouring Layer

5.5.3.1 Material

The contouring layer across Cell 2 was constructed directly above the select impacted material layer. The contouring layer material consists of fill material from on-site borrow sources described in Section 5.4. The results of standard Proctor compaction tests performed on select compacted fill material (see Table 5-2 and Appendix E) were used as reference for the compaction and testing of the contouring layer.

5.5.3.2 Construction Procedure

The minimum 1-ft (0.3-m) thick contouring layer was constructed in two lifts, with the first lift being of a 10 in. (250 mm) loose thickness. Each lift was 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 smooth drum roller. During placement and compaction, CQA personnel monitored the contractor's activities, including removal of visible rock particles larger than 4 in. (100 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 (total of 2) of contouring layer. These tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. A total of 104 field nuclear moisture/density tests were performed on the contouring layer, with 60 tests for the first lift and 44 tests for the second lift. The resulting frequency is 1.1 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 5-2). In addition, five (5) drive cylinder tests (ASTM D 2937) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 passing 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). All tests passed this performance testing criteria. The holes left from the moisture/density tests were filled with soil-bentonite mixture. The results of the field moisture/density tests performed on the contouring layer are presented in Appendix G.

Proof rolling

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

5.5.3.4 Certification

The surveyed areas of the surface of the contouring layer 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, with a minimum thickness of 1 ft (0.3 m), as required by the Project Documents. The as-built top of contouring layer certification drawings, prepared by Tecumseh (Fluor Fernald's surveyor), are included in Appendix Q.

5.5.4 Compacted Clay Cap

After completing the contouring layer construction operations, CQA personnel monitored the placement and compaction of the clay cap material by FFC. The compacted clay cap consisted of a minimum of 2 ft (0.6 m) thick layer, as shown on the CFC Drawings, placed and compacted in lifts, as described below.

5.5.4.1 Materials

The compacted clay cap 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 cap were: (i) processed on-site using a bar screening plant and stockpiled in preparation for transportation to the Cell 2 construction area; (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 (ii) 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 cap 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 cap construction for Cell 1 final cover system. The construction sequence of the compacted clay cap is described below:

- the contouring layer 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-6 LGP 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 and/or 825 sheepsfoot compactors making a minimum of six one-way passes;

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- 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 a GPS system for grade control;

- a D-6 LGP bulldozer was used in conjunction with GPS survey system to grade the compacted clay cap surface;

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

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

The compacted clay cap was generally constructed in four compacted lifts to a total thickness of 2 ft (0.6 m), as shown on the CFC Drawings. The contractor periodically added water during or after compacted clay cap placement and compaction to limit drying or desiccation cracking of the surface.

GeoSyntec CQA personnel monitored the compacted clay cap placement and compaction process described above. CQA personnel visually monitored that FFC utilized six or more passes with the compactor across the clay cap lift. CQA personnel also visually monitored that FFC protected completed compacted clay cap 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 cap surface was observed, FFC was instructed to moisture condition and rework the affected area.

5.5.4.3 Field Testing Activities

CQA personnel performed in-place nuclear moisture/density tests as the clay cap 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 9 acres (3.6 hectares), a minimum of 45 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 Cell 2 compacted clay cap (see Table 5-3). A total of 297 field moisture/density tests were performed on the Cell 2 compacted clay cap, with an average of 74 tests per lift. In addition, 16 drive cylinder tests (ASTM D 2932) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 passing nuclear moisture/density tests.

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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 25 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 recompacted the area surrounding the failure and then CQA personnel retested the area. This procedure was repeated until satisfactory moisture/density test results were obtained.

The results of the field moisture/density tests are presented in Appendix G. The holes left from the moisture/density tests, were filled with bentonite granules and 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 cap were found to be within the tolerances of +0 to +0.3 ft (+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 cap certification drawing, prepared by Tecumseh (Fluor Fernald's surveyor), is included in Appendix Q.

5.5.5 Cover Drainage Layer

5.5.5.1 Material

CQA personnel monitored the placement of the cover drainage layer material for the Cell 2 final cover. The cover drainage layer was constructed using granular material obtained from Martin Marietta, as described in Section 5.4. The cover drainage material was stockpiled in an area west of the Cell 2 final cover construction area.

5.5.5.2 Construction Procedure

The construction sequence of the cover drainage 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 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-6 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 cover drainage 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 cover drainage layer material was maintained over the geosynthetics, and that a 3-ft (0.9-m) thick layer of cover 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 cover drainage layer was surveyed and certified by Tecumseh. The surveyed areas of the surface of the cover drainage layer were found to be within the project tolerances of 0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built top of cover drainage layer, prepared by Tecumseh, is included in Appendix Q.

5.5.6 Biointrusion Barrier and Choke Stone Layer

5.5.6.1 Materials

CQA personnel monitored the placement of the biointrusion barrier and choke stone layer materials for the Cell 2 final cover. The biointrusion barrier and choke stone layer was constructed using granular materials obtained from Hanson's Highland and Eagle and Martin Marietta quarries, as described in Section 5.4. The materials were stockpiled in an area west of the Cell 2 final cover construction area.

5.5.6.2 Construction Procedure

The construction sequence of the biointrusion barrier and choke stone layer was as follows:

- Volvo articulated dump trucks hauled the biointrusion material from the stockpile to the cell area using a minimum 3-ft (0.9-m) thick haul roads constructed of the granular material;
- the biointrusion barrier material was spread in approximately one 1-ft (0.3-m) thick (loose) lift using Caterpillar D-6 LGP bulldozers;

- the choke stone material were then hauled and spread over the top of the biointrusion barrier material; and
- the bulldozer and Volvo articulated dump trucks were used to compact or track-in the choke stone to the final design grades.

5.5.6.3 Field Monitoring Activities

During placement of the biointrusion barrier and choke stone layer, CQA personnel periodically monitored the contractor's activities to assure that the risk of damage to the underlying geosynthetics was minimized. CQA personnel also checked that a 3-ft (0.9-m) thick layer of granular material was maintained over the underlying geosynthetics in heavily-trafficked areas.

5.5.6.4 Certification

Upon completion of grading and tracking using the bulldozer and articulated dump trucks, the surface of the biointrusion barrier layer was surveyed and certified by Tecumseh. The surveyed areas of the surface were found to be within the project tolerances of -0.1 to +0.3 ft (-0.03 to +0.09 m) of the thickness shown on the CFC Drawings. The as-built top of biointrusion barrier layer, prepared by Tecumseh, is included in Appendix Q.

5.5.7 Granular Filter Layer

CQA personnel monitored the placement operations for the granular filter layer. The granular filter was constructed using Type A-3 sand material obtained from off-site borrow sources, as indicated in Section 5.4. The material was placed in a nominal 6-in. (150-mm) thick loose lift and was tracked with a Caterpillar D-6 LGP bulldozer.

Upon completion of grading and tracking, the surface of the granular filter layer was surveyed and certified by Tecumseh. The surveyed areas of the surface were found to be within the project tolerances of 0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built top of granular filter layer, prepared by Tecumseh, is included in Appendix Q.

5.5.8 Vegetative Soil Layer

5.5.8.1 Material

The vegetative soil layer across Cell 2 was constructed directly above the granular filter layer. The vegetative soil layer material consisted of fill material from on-site borrow sources described in Section 5.4. The results of standard Proctor compaction

tests performed on select compacted fill material (see Table 5-9 and Appendix E) were used as reference for the compaction and testing of the vegetative soil layer.

5.5.8.2 Construction Procedure

The minimum 1.75-ft (0.53-m) thick layer was constructed in three lifts, with the first lift being of a 10 in. (250 mm) loose thickness. Each lift was compacted to a minimum degree of compaction of 92 percent of the maximum dry unit weight and within ±4 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). The subsequent lifts of fill material was placed and spread in 8-in. (200-mm) ±1 in. (25-mm) thick loose lifts using Volvo A35C articulated dump trucks and using Caterpillar D-6 LGP bulldozers to spread the material. The horizontal lifts were compacted using the bulldozer tracks and sealed with a smooth drum roller. During placement and compaction, CQA personnel monitored the contractor's activities, including removal of visible rock particles larger than 4 in. (100 mm), roots and other deleterious material; and minimizing large clods by breaking them with the bulldozer tracks.

5.5.8.3 Field Testing Activities

CQA personnel performed in-place nuclear moisture/density tests on compacted lifts of vegetative soil layer. These tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. A total of 90 field nuclear moisture/density tests were performed on the vegetative soil layer, with an average of 30 tests per lift. The resulting frequency is 3.4 tests/acre/lift, which exceeds the minimum frequency of 2 tests/acre/lift (5 tests/hectare/lift) required by the CQA Plan (see Table 5-9). In addition, 5 drive cylinder tests (ASTM D 2937) were performed as correlation tests to meet the minimum testing frequency of one test per 25 passing 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 92 percent of the maximum dry unit weight and within ±4 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). All tests passed this performance testing criteria. The holes left from the moisture/density tests were filled with soil-bentonite mixture. The results of the field moisture/density tests performed on the vegetative soil layer are presented in Appendix G.

5.5.8.4 Certification

The surveyed areas of the surface of the vegetative soil layer were found to be within the project tolerance of ±0.1 ft (±0.03 m) of the thickness required by the Project Documents. The as-built top of vegetative soil layer certification drawing, prepared by Tecumseh (Fluor Fernald's surveyor), is included in Appendix Q.

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5.5.9 Topsoil

GeoSyntec's on-site CQA personnel periodically monitored the hauling and placement of topsoil over the surface of the vegetative soil layer. Topsoil placement operations were performed by FFC. The topsoil material was transported from designated stockpiles in the OSDF construction area. CQA personnel periodically monitored the topsoil placement operations to assure the following:

- approved equipment was used for topsoil placement;
- the surface of the vegetative soil layer was scarified to the depths required by the Specifications; and
- a minimum thickness of 6 in. (150 mm) of topsoil was placed over the vegetative soil layer.

The surveyed areas of the surface of the topsoil were found to be within the project tolerances of ±0.1 ft (±0.03 m) of the thickness and within 0 to +0.5 ft (0 to 0.15 m) of the grades required by the Project Documents. The as-built top of topsoil layer certification drawing, prepared by Tecumseh, is included in Appendix Q.

5.5.10 Vegetation

Seeding of the topsoil was performed by FFC with the assistance of a landscape contractor. The seed mix and application rates are presented in Appendix F. Seeding of the Cell 2 final cover was performed using the seed-drill method, as required by the Technical Specifications. Erosion mat was manually installed and stapled over the seeded topsoil in accordance with the manufacturer's recommendations and the Project Documents (see Section 6.8).

GeoSyntec CQA personnel periodically monitored the seeding and installation of the erosion mat over the Cell 2 final cover.

5.6 Cell 6 Liner Field Monitoring Activities

5.6.1 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 CM for review and correction.

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5.6.2 Excavation

CQA personnel monitored excavation operations within the Cell 6 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 Cell 6 liner. In particular, excessive topsoil that was encountered within the Cells 6 and 7 footprints were removed, loaded in articulated dump trucks, and stockpiled in designated stockpile areas (see Appendix B for photographic documentation).

5.6.3 Subgrade

The Cell 6 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.

5.6.3.1 Material

The compacted fill material used within the subgrade and perimeter berms consisted 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).

5.6.3.2 Construction Procedure

The cell floor was 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 proof roll, 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.

5.6.3.3 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 386 field nuclear moisture/density tests were performed on the compacted fill, including the perimeter berms and Cell 2 final cover subgrade areas. This exceeds the minimum frequency of 1 test/10,000 ft^2/lift required by the CQA Plan (see Table 5-1). In addition, 16 drive cylinder tests (ASTM D 2937) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 passing 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.

Proof rolling

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

5.6.3.4 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 drawing for Cell 6, prepared by Tecumseh, is included in Appendix Q.

5.6.4 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.

5.6.4.1 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 in Section 5.5.4.1, clay liner and cap materials used for the compacted clay liner were processed on-site using a bar screening plant and stockpiled in preparation for transportation to the Cell 6 construction area.

5.6.4.2 Construction Procedure

Construction of the compacted clay liner was performed in accordance with the Project Documents and patterned after the Test Pad Program as described in Section 5.5.2 for the compacted clay cap for the Cell 2 final cover. The construction sequence of the Cell 6 liner compacted clay liner is the same as described in Section 5.5.4.2 for the Cell 2 final cover compacted clay cap.

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.

5.6.4.3 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 7.2 acres (2.9 hectares), a minimum of 36 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 Cell 6 compacted clay liner (see Table 5-3). A total of 482 field moisture/density tests were performed on the Cell 6 compacted clay liner,

with an average of 80 tests per lift. In addition, 26 drive cylinder tests (ASTM D 2932) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 passing 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 19 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 5-3. 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.

5.6.4.4 Certification

The surveyed areas of the surface of the compacted clay liner were found to be within the tolerances of +0 to +0.3 ft (+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 Cell 6 compacted clay liner certification drawing, prepared by Tecumseh, is included in Appendix Q.

5.6.5 Leak Detection System Layer

5.6.5.1 Material

CQA personnel monitored the placement of the LDS layer for the Cell 6 liner system. The 1-ft (0.3-m) thick LDS layer was constructed using granular drainage material obtained from Martin Marietta Aggregates, as described in Section 5.4. The LDS drainage material was stockpiled in an area south of the Cell 6 construction area.

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

5.6.5.2 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.

5.6.5.3 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.

5.6.5.4 Certification

Upon completion of grading and tracking using the bulldozer, the surface of the LDS layer was surveyed and certified by Tecumseh. The surveyed areas of the surface of the LDS layer were found to be within the project tolerances of 0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built drawing for the top of LDS layer for Cell 6, prepared by Tecumseh, is included in Appendix Q.

5.6.6 Leachate Collection System Layer

5.6.6.1 Material

CQA personnel monitored the placement of the LCS drainage layer and drainage corridor materials for Cell 6. The 1-ft (0.3-m) thick LCS drainage layer was constructed using granular drainage material obtained from Martin Marietta Aggregates. The LCS drainage corridor material was constructed using granular drainage material obtained from Welch. The granular drainage materials were stockpiled in an area south of the Cell 6 construction area.

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5.6.6.2 Construction Procedure

The LCS layer was constructed in the same sequence as described in Section 5.6.5.2 for the LDS layer.

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.

5.6.6.3 Certification

Upon completion of grading and tracking using the bulldozer, the surface of the LCS layer was surveyed and certified by Tecumseh. The surveyed areas of the surface of the LCS layer were found to be within the project tolerances of 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 Cell 6, prepared by Tecumseh, is included in Appendix Q.

5.6.7 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 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 drawing for the top of protective layer for Cell 6, prepared by Tecumseh, is included in Appendix Q.

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5.6.8 Soil Anchorage of Geosynthetics

5.6.8.1 General

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

5.6.8.2 Perimeter Anchor Trenches

As required by the Project Documents, anchor trenches were constructed around the east and west perimeters of the Cell 6 construction area. 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 Cell 6 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 Cell 6 perimeter berms, approximately 7 ft (2.1 m) from the crest of the slope; and
- the primary liner system geosynthetics (i.e., GCL, geomembrane liner, and geotextile cushion) were placed in the anchor trench behind the secondary liner system geosynthetics, and lifts of compacted clay material were placed into the anchor trench and compacted.

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

- backfill material was obtained from the processed 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
CELL 2 FINAL COVER AND CELL 6 LINER

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	10	14
Standard Proctor Compaction	ASTM D 698	—	1 per 5,000 yd^3	10	14
Moisture	ASTM D 2216 ASTM D 4643	—	1 per 5,000 yd^3	10	14
Soil Classification	ASTM D 2487	GC, SC, SM, ML, CL or CH	1 per 5,000 yd^3	10	14
Atterberg Limits	ASTM D 4318	—	1 per 5,000 yd^3	10	14
FIELD TEST					
Drive Cylinder					
Soil density	ASTM D 2937	≥95% MDD[3]	1 per 25 passing nuclear tests	16	18
Soil moisture	ASTM D 2216	± 3% OMC		16	18
Nuclear Gauge:			2/acre/lift		
Soil density	ASTM D 2922	≥95% MDD		152	386 (21)
Soil moisture	ASTM D 3017	± 3% OMC		152	386 (21)

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 46,400 yd^3 for the Cell 2 final cover and Cell 6 liner construction project.
(3) MDD = maximum dry density (unit weight); OMC = optimum moisture content

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TABLE 5-2

CONTOURING LAYER PROPERTIES SUMMARY
CELL 2 FINAL COVER

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 4.0 in.	1 per 5,000 yd^3	3	3 (0)
Standard Proctor Compaction	ASTM D 698	---	1 per 5,000 yd^3	3	3
Moisture Content	ASTM D 2216 ASTM D 4643	---	1 per 5,000 yd^3	3	3
Soil Classification	ASTM D 2487	GC, SC, CL	1 per 5,000 yd^3	3	3 (0)
Atterberg Limits	ASTM D 4318	---	1 per 5,000 yd^3	3	3 (0)
FIELD TEST					
Drive Cylinder					
Soil density	ASTM D 2937	≥92% MDD	1 per 25 passing nuclear tests	4	5
Soil moisture	ASTM D 2216	± 3% OMC		4	5
Nuclear Gauge:			2/acre/lift		
Soil density	ASTM D 2922	≥92%		36	104 (4)
Soil moisture	ASTM D 3017	± 3% OMC		36	104 (4)

NOTES: (1) Reference Section 02240 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 14,407 yd^3 for the Cell 2 final cover construction project.
(3) MDD = maximum dry density (unit weight); OMC = optimum moisture content

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TABLE 5-3
COMPACTED CLAY LINER AND CAP PROPERTIES SUMMARY
CELL 2 FINAL COVER AND CELL 6 LINER

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 & Hydrometer Percent Finer than 2.0 in. Percent Finer than 0.75 in. Percent Finer than No. 200 Percent Finer than 0.002 mm	ASTM D 422	 100% ≥90% ≥50% ≥15%	1 per 1,500	75	75 (0)
Compaction Standard/Modified	ASTM D 698/ ASTM D 1557	---	1 per 1,500/ as required	75	75 (0)/40 (0)
Moisture Content	ASTM D 2216 ASTM D 4643	---	1 per 1,500/ as required	75	75 (0)
Soil Classification	ASTM D 2487	CL or CH	1 per 1,500	75	75 (0)
Atterberg Limits	ASTM D 4318	$10 \leq PI \leq 40$	1 per 1,500	75	76 (1)
Hydraulic Conductivity: Individual samples (Remold) Composite samples (Remold)	ASTM D 5084	$\leq 1 \times 10^{-7}$ cm/s	1 per 10,000 and 1 per stockpile	13 13	14 (1) 17 (4)
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	Cell 2 Cap 12 Cell 6 Liner 20	Cell 2 Cap 16 Cell 6 Liner 26
Nuclear Gauge: Soil density Soil moisture	ASTM D 2922 ASTM D 3017	Within APZ and ≥95% MDD 0 - 3% OMC	5/acre/lift	Cell 2 Cap 179 Cell 6 Liner 246	Cell 2 Cap 297 (25) Cell 6 Liner 482 (19)
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 and cap for the Cell 2 final cover and Cell 6 liner construction projects.
(3) Failing nuclear density/moisture tests were reworked until passing results were obtained (see Section 5.5.4 of report).

TABLE 5-4

GRANULAR DRAINAGE LAYER MATERIAL (NO. 78 STONE) CELL 2 FINAL COVER AND CELL 6 LINER

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	14	19 (0)
Soil Classification	ASTM D 2487	GP	1 per 3,000 yd^3	14	19 (0)
Carbonate Content	ASTM D 3042	$\leq$5%	1 per 5,000 yd^3	8	12 (0)
Hydraulic Conductivity	ASTM D 2434	$\geq$ 0.1 cm/s	1 per 3,000 yd^3	14	16 (0)
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 39,950 yd^3 for the Cell 2 final cover and Cell 6 liner construction projects.

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TABLE 5-5

GRANULAR DRAINAGE CORRIDOR MATERIAL (NO. 57 STONE) CELL 6 LINER

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	1	5 (0)
Soil Classification	ASTM D 2487	GP	1 per 3,000	1	5 (0)
Carbonate Content	ASTM D 3042	≤5%	1 per 5,000	1	2 (0)
Hydraulic Conductivity: Granular	ASTM D 2434	≥10 cm/s	1 per 3,000	1	2 (0)
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 2,235 yd^3 for the Cell 6 liner construction project.

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TABLE 5-6

BIOINTRUSION BARRIER LAYER PROPERTIES SUMMARY (TYPE D RIPRAP) CELL 2 FINAL COVER

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Bulk Specific Gravity	ASTM C 127	≥2.60	1 per 10,000yd^3	5	6 (0)
Absorption	ASTM C 127	≤2%	1 per 10,000yd^3	5	6 (0)
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 43,220 yd^3 for the Cell 2 final cover construction project.

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TABLE 5-7

BIOINTRUSION CHOKE STONE PROPERTIES SUMMARY (NO. 57 STONE) CELL 2 FINAL COVER

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 05 - 10 No. 8 0 - 5	1 per 10,000 yd^3	1	3 (0)
Soil Classification	ASTM D 2487	GP	1 per 10,000 yd^3	1	3 (0)
Bulk Specific Gravity	ASTM C 127	≥2.60	1 per 10,000 yd^3	1	1 (0)
Absorption	ASTM C 127	≤2%	1 per 10,000 yd^3	1	1 (0)
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 3,600 yd^3 for the Cell 2 final cover construction project.

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TABLE 5-8

GRANULAR FILTER MATERIAL PROPERTIES SUMMARY (ODOT TYPE A-3 SAND) CELL 2 FINAL COVER

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	No. 4 100 No. 50 95 - 100 No. 200 25 - 60	1 per 5,000yd^3	2	5 (0)
Soil Classification	ASTM D 2487	SW, SP	1 per 5,000yd^3	2	5 (0)
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	---	---	---

NOTES: (1) Reference Section 02712 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 7,200 yd^3 for the Cell 2 final cover construction project.

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TABLE 5-9

VEGETATIVE SOIL LAYER PROPERTIES SUMMARY
CELL 2 FINAL COVER

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 4.0 in.	1 per 5,000 yd^3	6	7 (0)
Standard Proctor Compaction	ASTM D 698	---	1 per 5,000 yd^3	6	7 (0)
Moisture Content	ASTM D 2216 ASTM D 4643	---	1 per 5,000 yd^3	6	7 (0)
Soil Classification	ASTM D 2487	GC, SC, CL	1 per 5,000 yd^3	6	7 (0)
Atterberg Limits	ASTM D 4318	---	1 per 5,000 yd^3	6	7 (0)
FIELD TEST					
Drive Cylinder Soil density Soil moisture	 ASTM D 2937 ASTM D 2216	 ≥92% MDD ± 3% OMC	1 per 25 passing nuclear tests	 4 4	 5 (0) 5 (0)
Nuclear Gauge: Soil density Soil moisture	 ASTM D 2922 ASTM D 3017	 ≥92% ± 3% OMC	2/acre/lift	 54 54	 90 (0) 90 (0)

NOTES: (1) Reference Section 02250 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 25,210 yd^3 for the Cell 2 final cover construction project.
(3) MDD = maximum dry density (unit weight); OMC = optimum moisture content

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TABLE 5-10

TOPSOIL PROPERTIES SUMMARY
CELL 2 FINAL COVER

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	No. 10 0 - 40	1 per 5,000 yd^3	2	2 (0)
Organic Content	ASTM D 698	---	1 per 5,000 yd^3	2	2 (0)
Soil Classification	ASTM D 2487	GC, SC, CL	1 per 5,000 yd^3	2	2 (0)
Atterberg Limits	ASTM D 4318	---	1 per 5,000 yd^3	2	2 (0)
FIELD TEST					
Depth Verification: Survey	ASTM D 2937	As shown on drawings	---	---	---

NOTES: (1) Reference Section 02920 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 7,200 yd^3 for the Cell 2 final cover construction project.

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6. CONSTRUCTION QUALITY ASSURANCE - GEOSYNTHETICS

6.1 General

GeoSyntec monitored the installation of the geosynthetics components of the Cell 2 final cover system and Cell 6 double-composite liner system. Principal field activities are summarized in Section 3.1.3. Non-conforming or questionable practices observed by CQA personnel were brought to the attention of the Fluor Fernald QA and the CM for review and correction.

The total quantity of geomembrane installed during the Phase IV – Cell 2 final cover construction, as measured by CQA personnel, was 327,594 ft^2 (30,474 m^2). The total quantity of geomembrane installed during the Phase V – Cell 6 liner construction, as measured by CQA personnel, was 604,299 ft^2 (56,215 m^2), which consists of the primary liner geomembrane and secondary liner geomembrane, including the anchor trenches. The panel layout record drawings for the Cell 2 final cover and Cell 6 primary liner and secondary liner geomembrane 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 FCP 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 the Phase IV – Cell 2 final cover and Phase V – Cell 6 liner construction projects are presented in Appendices S and T, respectively.

6.3 CQA of Geosynthetic Clay Liner and Cap

6.3.1 Conformance Testing and Documentation

A geosynthetic clay liner and cap (GCL and GCC) was used in construction of the Cell 2 final cover and Cell 6 double composite liner systems. Rolls of the Bentomat ST GCL, manufactured by Colloid Environmental Technologies Company (CETCO) in Lovell, Wyoming were used for the Cell 2 final cover and Cell 6 liner system construction.

For the Bentomat ST GCL, 13 samples (Nos. GCL 03-1 through GCL 03-13) from GCL Lot No. 200304LO and 200305LO 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 2003. All of the 13 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 Cell 2 final cover and Cell 6 liner GCL and GCC approval is presented in Table 6-1. The manufacturer's QC documentation is presented in Appendix F. GeoSyntec's conformance test results are presented in Appendix H. A summary of the physical properties of the GCL and GCC 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 and GCC rolls were unloaded in a laydown area located in the northeast corner of the OSDF construction area and covered with a tarpaulin. The GCL and GCC 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 and GCC rolls for the Cell 6 liner and Cell 2 final cover, respectively. 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 and GCC, 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 or GCC was unrolled and placed in a manner which kept the roll of GCL or GCC in sufficient tension to avoid excessive wrinkling using LGP 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 and GCC panels;
- measures were taken to avoid damage to the underlying clay surface during deployment of the rolls;
- measures were taken to keep the GCL and GCC free of contamination and protected from premature hydration; and
- geomembrane installation immediately followed installation of the GCL and GCC.

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

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

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seams of overlapped panels in accordance with the GCL and GCC manufacturer's recommendation.

Observed holes or tears in the GCL and GCC 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 or GCC was detected, the GCL or GCC was removed and replaced with new approved material.

6.4 CQA of Geomembrane Liner and Cap

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 Cell 2 final cover and Cell 6 liner construction, geomembrane conformance samples were taken randomly from the 80-mil (2.0-mm) thick HDPE textured geomembrane rolls used to construct the final cover and liner systems. A total of 12 conformance samples were obtained by CQA personnel at the manufacturing plant prior to delivery to the site. These samples represented 5 lots of geomembrane, which comprised 131 geomembrane rolls. The total number of conformance samples exceeded 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 welding rod. CQA personnel obtained one letter of certification for the extrudate welding rod during construction of Cell 2 final cover and Cell 6 liner. The certification letter is presented in Appendix F.

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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 and GCC panels using procedures approved by the CM to assure no damage to the GCL and GCC. The installer generally deployed the geomembrane panels, in accordance with the approved panel layout drawings from:

<u>Cell 2 Final Cover</u>

- east to west across the west slopes from the 10H:1V slopes,
- west to east across the east slopes from the 10H:1V slopes, and
- north to south across the 20H:1V top slopes; and

<u>Cell 6 Liner</u>

- south to north across the Cell 6/Cell 7 intercell berm,
- east to west across the cell floor from the east perimeter berm, and
- west to east for tie-in at the cell floor from the west perimeter berm.

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;

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- 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.

During deployment of the geomembrane for the Cell 2 final cover and Cell 6 secondary and primary liners, manufacturing defects were observed on the geomembrane rolls manufactured and supplied by GSE. The defects appeared as excess extrudate, in the form of blisters of polymer, which were attached on the geomembrane rolls during production, and typically close to the smooth edges. When these excess extrudate materials were removed, holes were typically found in the manufactured geomembrane material. It appears that clogging of the nozzles during the injection process of the nitrogen gas for the texturing phase of the production resulted in the formation of polymer blisters on the manufactured geomembrane. Photographic documentation of these manufacturing defects are presented in Appendix B.

The larger manufacturing defects were removed by cutting out the area and repairing with a geomembrane patch. The small size defects were typically repaired by grinding the area and replacing with an extrudate bead. Details on geomembrane repairs are described in Section 6.4.5.

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

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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) for the 80-mil thick geomembrane seams in the Cell 2 final cover and Cell 6 liner,
- *Peel test* - a minimum bonded seam strength of 88 lb/in. (15 kN/m) and the observation of a FTB for the tie-in of the 60-mil thick geomembrane in Cell 1 final cover to the 80-mil thick geomembrane in the Cell 2 final cover (hereafter referred to as Cell 1/Cell 2 tie-in),
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (26 kN/m) and the observation of a FTB for the 80-mil thick geomembrane seams in the Cell 2 final cover and Cell 6 liner, and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m) and the observation of a FTB for the Cell 1/Cell 2 tie-in; and

Extrusion

- *Peel test* - a minimum bonded seam strength of 84 lb/in. (15 kN/m) and the observation of a FTB for the 80-mil thick geomembrane seams in the Cell 2 final cover and Cell 6 liner,
- *Peel test* - a minimum bonded seam strength of 63 lb/in. (11 kN/m) and the observation of a FTB for the Cell 1/Cell 2 tie-in,
- *Shear test* - a minimum bonded seam strength of 151 lb/in. (26 kN/m); and the observation of a FTB for the 80-ml thick geomembrane seams in the Cell 2 final cover and Cell 6 liner, and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m) and the observation of a FTB for the Cell 1/Cell 2 tie-in;
- 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 88 trial seams were observed by CQA personnel during Cell 2 final cover construction. A total of 42 trial seams were made using double-track fusion (i.e., hot wedge) welders and 46 were made using extrusion welders. For the Cell 6 liner construction, a total of 176 trial seams were observed by CQA personnel. A total of 95 trial seams were made using double-track fusion (i.e., hot wedge) welders and 81 were made using extrusion welders. A total of 25 trial seams failed (9 fusion seams and 16 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 Cell 2 final cover and Cell 6 liner construction season. Production seaming activities were not performed below 40°F (5°C) during the Phase IV – Cell 2 final cover and Phase V – Cell 6 liner construction projects.

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 35 original geomembrane seam sample locations were identified during Cell 2 final cover construction (Table 6-4). Approximately 16,011 linear ft (4,883 linear meters) of seams was constructed. This corresponds to an approximate sample frequency of one per 457 linear feet (140 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.

A total of 75 (33 on secondary and 42 on primary) original geomembrane seam sample locations were identified during Cell 6 liner construction (Table 6-5). Approximately 32,513 linear ft (9,916 linear meters) of seams were constructed. This corresponds to an approximate sample frequency of one per 434 linear feet (132 linear meters) of seam. This frequency meets the minimum acceptable sample frequency of one per 500 linear feet (132 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.

The following criteria were used for the 80-mil thick geomembrane seams:

Fusion

- *Peel test* - a minimum bonded seam strength of 115 lb/in. (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; and

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.

For the Cell 1/Cell 2 tie-in the following seam strength criteria were used as previously described in Section 6.4.2.3:

Fusion

- *Peel test* - a minimum bonded seam strength of 88 lb/in. (15 kN/m) and the observation of a FTB, and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m); and the observation of a FTB; and

Extrusion

- *Peel test* - a minimum bonded seam strength of 63 lb/in. (11 kN/m); and the observation of a FTB, and

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- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 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 Cell 2 final cover, 3 failures were recorded on the initial destructive seam samples; 1 of the failures occurred in the field test strips and 2 failures in the laboratory destructive samples (Table 6-4).

For the Cell 6 liner, 17 failures were recorded on the initial destructive samples; 7 failures occurred in the field test strips and 10 failures occurred in the laboratory destructive samples (Table 6-5).

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. For the Cell 2 final cover, 4 additional seam samples were obtained to isolate the failure and on the reconstructed seams, as indicated in Table 6-4. For the Cell 6 liner, 67 additional seam

samples were obtained to isolate failures and on reconstructed seams, 51 on the primary liner geomembrane and 16 on the secondary liner geomembrane, as indicated in Table 6-5.

Seams having failing destructive samples were repaired using procedures presented in Section 6.4.5. The destructive seam test sample locations were also repaired using the procedures 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.

The results of the destructive tests summarized above and in Tables 6-4 and 6-5 indicate that significantly high additional number of samples were taken to isolate failures with the Cell 6 primary liner geomembrane compared to the Cell 2 cap geomembrane and Cell 6 secondary liner geomembrane. As additional samples were taken to isolate failures and on reconstructed seams on the primary liner geomembrane, more failures were encountered with the reconstructed seams completed with extrusion welding technique. Preliminary investigations conducted suggested that the problems encountered during the extrusion-seam welding of the Cell 6 primary liner geomembrane were primarily due to the extrudate welding rods used to perform the extrusion welding. Details of the investigations, findings and recommendations were documented in a memorandum titled "Preliminary Evaluation of Potential Problem with Extrudate Welding Rods" from GeoSyntec to Fluor Fernald, dated 23 September 2003. A copy of this memorandum is provided in Appendix C (see Correspondence).

The recommendations in the above memorandum were followed to repair suspect extrusion seams except for small seams that included patches at destructive test locations, T-seams and patches for small holes, tears, etc. Following these repairs additional testing was performed to comply with the project and regulatory requirements, as described below.

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 Cell 2 final cover geomembrane, Cell 6 secondary liner geomembrane, and the Cell 6 primary liner geomembrane. Seam and panel repair locations are presented in Appendix O. Complete panel layout drawings indicating the location of seam and panel repairs are 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 Cell 2 final cover geomembrane and the Cell 6 primary liner geomembrane. 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. The testing was performed on the exposed (or bare) geomembrane prior to installation of the overlying geotextile cushion and placement of the granular drainage material. For the Cell 6 primary liner geomembrane, however, a second leak detection testing was conducted after placement of the overlying geotextile cushion and granular drainage layers. This additional testing was conducted in response to comments from the regulatory agencies (USEPA and OEPA) to the memorandum describing the potential problems with the extrudate welding rods in Section 6.4.4. Documentation on the correspondence from Fluor Fernald and DOE to USEPA and OEPA is provided in Appendix C (see Correspondence).

For the Cell 2 final cover geomembrane five (5) leaks were detected during testing. Six (6) leaks were located on the Cell 6 primary liner exposed geomembrane that was tested.

Three leaks were located in the Cell 6 primary liner geomembrane after placement of the geotextile cushion and 1-ft (0.3-m) thick granular drainage layer. The detected leaks were repaired by the installer following the repair procedures described in this Section. The repaired areas were retested by LLSI and no additional leaks were found.

Appendix P presents three reports on the electrical leak detection testing which was conducted as part of the OSDF Phase IV – Cell 2 final cover and Phase V – Cell 6 liner construction projects.

6.5 CQA of Geotextiles

6.5.1 Conformance Testing and Documentation

Four types of geotextile were used in construction of Cell 2 final cover and Cell 6 liner systems:

- A needle-punched 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 for the Cell 6 liner system. This geotextile was manufactured and supplied by TNS Advanced Technologies, Inc. (TNS), Spartanburg, South Carolina.

- A needle-punched nonwoven geotextile having a minimum mass per unit area of 8 oz/yd^2 (270 g/m^2) was used as the geotextile cushion layer for the Cell 2 final cover system. This geotextile was also manufactured and supplied by TNS.

- 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 for the Cell 6 liner system. This geotextile was also manufactured and supplied by TNS.

- 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 for both Cell 2 final cover and Cell 6 liner systems. This geotextile was also manufactured and supplied by TNS.

CQA personnel obtained 21 conformance samples from the 266 geotextile rolls delivered to the site. Five (5) conformance samples were obtained from 69 rolls of the Cell 6 geotextile filter; 5 conformance samples were obtained from the 60 rolls of the Cell 2 final cover geotextile cushion; 9 conformance samples were obtained from 117 rolls of the Cell 6 geotextile cushion, and 2 conformance samples were obtained from 20 rolls of the 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 Cell 6 geotextile filter, Cell 2 final cover geotextile cushion, Cell 6 geotextile cushion, and supplemental geotextile cushion is presented in Tables 6-6, 6-7, 6-8, and 6-9, 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 completed.

- 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 Penetration Boxes

Cell 6 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.

Following installation of the liner penetration boxes, including geomembrane connections and testing described above, leaks were suspected to be underneath Liner Penetration Box Type III that provided penetration of the LCS pipe through the primary liner geomembrane. The leaks were investigated by cutting the LCS pipe from the end of the box, to allow repairs around the pipe penetration, if necessary. No apparent leaks were found; however, it was observed that an additional flat stock had been attached to the base plate flat stock of the box. Water was trapped between the two plates, thereby making the box suspect of leaking. The pipe was reattached to the box using the extrusion welding technique.

6.7 CQA of Perforated HDPE Piping

CQA personnel monitored the installation of the various HDPE piping components of the LDS, LCS and RLCS for Cell 6. 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-6 from Cell 6 outlet;
- redundant LCS (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-6 from Cell 6 outlet; 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-6 from Cell 6 outlet.

6.7.1 Pipe Conformance Testing and Documentation

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

- 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 6in. (150-mm) nominal diameter HDPE SDR-11 RLCS perforated pipe.

The HDPE pipes within Cell 6 were connected to the liner penetration boxes described in Section 6.6. The perforated sections of the LDS, LCS and RLCS pipes were connected to the solid-wall sections of each pipe 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 liner. Leachate will be discharged through the liner penetration boxes within Cell 6 via gravity pipeline to the VH-6.

6.8 CQA of Erosion Mat

6.8.1 Material Types

Two types of erosion mat were used in construction of the Cell 2 final cover:

- a biodegradable, woven jute matting having a minimum mass per unit area of 14.7 oz/yd^2 (500 g/m^2) was used as the erosion mat for the Cell 2 final cover; this jute matting was manufactured and supplied by Indian Valley Industries, Inc. in Johnson City, New York; and

- a biodegradable, woven erosion mat, made of coir (coconut) fiber and having a minimum mass per unit area of 26.8 oz/yd^2 (900 g/m^2) was used as the erosion mat in specific locations of the Cell 2 final cover; this erosion mat was also manufactured and supplied by Indian Valley Industries, Inc. in Johnson City, New York.

The manufacturers' certificates for the two erosion mat products are presented in Appendix E.

6.8.2 Field Monitoring Activities

During installation of the erosion mat, CQA personnel periodically monitored the following:

- two panels (i.e., two roll widths) of the coir matting were installed at the specific locations required by the Construction Drawings and other project documents;

- erosion mat panels were overlapped in accordance with the manufacturers' recommendations; and
- adjacent panels were stapled in accordance with manufacturers' recommendations using a minimum 6 in. (150 mm) long staples.

TABLE 6-1

GEOSYNTHETIC CLAY LINER AND CAP CONFORMANCE TESTING APPROVAL SUMMARY
CELL 2 FINAL COVER AND CELL 6 LINER

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						
GCL-03-1	200304LO	450	437	430 447 464	PASS	PASS	429 - 472	18 April 2003	44	99,000
GCL-03-2	200304LO	495	482	481 498 515	PASS	PASS	473 - 516	14 April 2003	44	99,000
GCL-03-3	200304LO	540	527	532 549	PASS	PASS	517 - 546	09 April 2003	30	67,500
GCL-03-4	200305LO	568	572	566 583	PASS	PASS	547 - 590	04 April 2003	44	99,000
GCL-03-5	200305LO	612	617	600 617 634	PASS	PASS	591 - 634	04 April 2003	44	99,000
GCL-03-6	200305LO	657	662	651 668	PASS	PASS	635 - 678	04 April 2003	44	99,000
GCL-03-7	200305LO	702	707	685 702 719	PASS	PASS	679 - 722	09 April 2003	44	99,000
GCL-03-8	200305LO	746	751	736 752	PASS	PASS	723 - 766	09 April 2003	44	99,000
GCL-03-9	200305LO	790	795	770 787 804	PASS	PASS	767 - 810	14 April 2003	44	99,000
GCL-03-10	200305LO	834	839	821 838	PASS	PASS	811 - 854	14 April 2003	44	99,000
GCL-03-11	200305LO	878	883	855 872 889	PASS	PASS	855 - 898	14 April 2003	44	99,000
GCL-03-12	200305LO	921	927	906 923 940	PASS	PASS	899 - 942	18 April 2003	44	99,000
GCL-03-13	200305LO	941	NR	NP	PASS	NR	943 - 955	18 April 2003	13	29,250

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 – Cell 2 final cover and Phase V – Cell 6 liner constructions.
5. Square footage for total number of rolls given.

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TABLE 6-2

GEOSYNTHETIC CLAY LINER AND CAP PHYSICAL PROPERTIES SUMMARY CELL 2 FINAL COVER AND CELL 6 LINER

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	$\leq 5 \times 10^{-9}$	$\leq 5 \times 10^{-9}$	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: 527 Total No. of Conformance Samples: 13

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 Cell 6 liner and Cell 2 final cover 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 CELL 2 FINAL COVER AND CELL 6 LINER

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	29	12	131	12	240.1	224.4
Elongation at Yield (%)	ASTM D 638[5]	13	≥12	40,000	100,000	29	12	131	12	17.2	14.3
Break Strength (lb/in.)	ASTM D 638[5]	324	≥120 [6]	40,000	100,000	29	12	131	12	308.3	223.2
Elongation at Break (%)	ASTM D 638[5]	560	≥100	40,000	100,000	29	12	131	12	607	396
Thickness (mil)	ASTM D 5994	80 nominal 76 min.	Avg. 80 Min. 76	40,000	100,000	29	12	131	12	85.3	83.4
Specific Gravity (NA)	ASTM D 792 or ASTM D 1505	0.940	≥0.935 (resin) ≥0.940 (sheet)	40,000	100,000	29	12	33	12	0.948	0.946
Tear Resistance (lb)	ASTM D 1004 Die C Puncture	60	≥56	40,000	NA	29	NA		NA	NA	NA
Puncture Resistance (lb)	ASTM D 4833	120	≥120	40,000	NA	29	NA	131	NA	NA	NA
Carbon Black Content (%)	ASTM D 1603	2.0	2-3	40,000	100,000	29	12	33	12	2.77	2.45
Carbon Black Dispersion	ASTM D 5596	Category 1 or 2	Category 1 or 2	40,000	100,000	29	12	33	12	CAT. 1	CAT. 2
Low Temperature Brittleness (□°C)	ASTM D 746B	-75	-60 max.	400,000	NA	3	NA	4	NA	NA	NA
Dimensional Stability (%) (@ 212°F, 15 min.)	ASTM D 1204	±2 max.	±2 max.	400,000	NA	3	NA	4	NA	NA	NA
NCTL (hr)[6]	ASTM D 5397	500	≥500	400,000	NA	3	NA	4	NA	NA	NA
Asperity Height	GRI GM12	7	≥7	40,000	NA	29	NA	131	NA	NA	NA

Total Number of Rolls Delivered to Site: 131 (1,149,525 ft^2)

Total Number of Conformance Samples: 12

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 1,149,525 ft^2 for the Cell 6 liner and Cell 2 final cover installation.
(3) GSE Lining Technologies, Houston, Texas is the geomembrane supplier. Roll dimensions are 22.5 ft. x 390 ft. (avg. Length)
(4) Tests performed at a frequency of one per lot or at listed frequency, whichever is greater. A lot is as defined by ASTM 4354. Minimum test frequency of resin is 1 test per railcar.
(5) ASTM D 638 is modified by NSF-54 Annex A.
(6) Time-to-failure at a tensile stress of 30% of the tensile yield strength
(7) MARV = (minimum average roll value), 95 percent lower confidence limit.

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TABLE 6-4
80-MIL THICK HDPE GEOMEMBRANE (TEXTURED)
SEAM PROPERTIES SUMMARY
CELL 2 FINAL COVER CONSTRUCTION

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	32	35	1	2	4	39
	ASTM D 6392	FTB 151 ppi	FTB 151 ppi	150 lin. ft						

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. One non-FTB per five specimens is acceptable provided that the strength requirements are met.
(3) FTB = Film Tear Bond (maximum 10 percent seam separation)

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TABLE 6-5
80-MIL THICK HDPE GEOMEMBRANE (PRIMARY/SECONDARY) (TEXTURED)
SEAM PROPERTIES SUMMARY
CELL 6 LINER CONSTRUCTION

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]:							secondary	secondary	secondary	secondary
Production Welds	ASTM D 6392	FTB 115 ppi	FTB 84 ppi	500 lin. ft	secondary min. of 32	33	1	5	16	49
and							primary	primary	primary	primary
Reconstructed Seams	ASTM D 6392	FTB 151 ppi	FTB 151 ppi	150 lin. ft	primary min. of 34	42	6	5	51	93

Note: (1) Reference Section 02770 of the Specifications and Section 7 of the CQA Plan for further details.
(4) 1 in. wide test strips are tested at a strain rate of 2 in. per minute. One non-FTB per five specimens is acceptable provided that the strength requirements are met.
(5) FTB = Film Tear Bond (maximum 10 percent seam separation)

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TABLE 6-6

NONWOVEN GEOTEXTILE (7 oz/yd^2) FILTER PROPERTIES SUMMARY CELL 6 LINER

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	10	5	10	5	8.7	7.7
Mullen Burst Strength (psi)	ASTM D 3786	350	≥350	50,000	100,000	10	5	10	5	388	353
Grab Strength (lb)	ASTM D 4632	180	≥180	50,000	100,000	10	5	10	5	280	217
Tear Strength (lb)	ASTM D 4533	75	≥75	50,000	100,000	10	5	10	5	126.8	85
Puncture Strength (lb)	ASTM D 4833	75	≥75	50,000	100,000	10	5	10	5	191.5	125.9
Apparent Opening Size (mm) (A.O.S.)	ASTM D 4751	0.212	≤0.212	100,000	100,000	5	5	10	5	0.09	0.076
Permittivity (sec^{-1})	ASTM D 4491	0.5	≥0.5	100,000	100,000	5	5	10	5	1.48	1.44
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: 69

Total Number of Conformance Samples: 5

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 465,150 ft^2 available for Cell 6 liner 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 6-7

NONWOVEN GEOTEXTILE (8 oz/yd^2) CUSHION PROPERTIES SUMMARY
CELL 2 FINAL COVER

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	8	≥8	50,000	100,000	9	5	9	5	9.1	10.0
Burst Strength (psi)	ASTM D 3786	350	≥350	50,000	100,000	9	5	9	5	450	398
Grab Strength (lb)	ASTM D 4632	200	≥200	50,000	100,000	9	5	9	5	299	245
Tear Strength (lb)	ASTM D 4533	75	≥75	50,000	100,000	9	5	9	5	140	93
Puncture Strength (lb)	ASTM D 4833	90	≥90	50,000	100,000	9	5	9	5	162	146
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: 60

Total Number of Conformance Samples: 5

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 405,000 ft^2 available for Cell 2 final cover 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 6-8

NONWOVEN GEOTEXTILE (10 oz/yd^2) CUSHION PROPERTIES SUMMARY CELL 6 LINER

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	16	8	17	9	11.4	10.0
Burst Strength (psi)	ASTM D 3786	450	≥450	50,000	100,000	16	8	17	9	575	489
Grab Strength (lb)	ASTM D 4632	225	≥225	50,000	100,000	16	8	17	9	393	302
Tear Strength (lb)	ASTM D 4533	90	≥90	50,000	100,000	16	8	17	9	175	114.2
Puncture Strength (lb)	ASTM D 4833	120	≥120	50,000	100,000	16	8	17	9	206	166.6
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: 117

Total Number of Conformance Samples: 9

Notes:
(1) Reference Section 02714P of the Specifications and Section 9 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total of 789,750 ft^2 available for Cell 6 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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TABLE 6-9

NONWOVEN GEOTEXTILE (16 oz/yd^2) SUPPLEMENTAL CUSHION PROPERTIES SUMMARY CELL 2 FINAL COVER AND CELL 6 LINER

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	16	≥16	50,000	100,000	3	2	3	2	17.3	16.3
Burst Strength (psi)	ASTM D 3786	700	≥700	50,000	100,000	3	2	3	2	837	773
Grab Strength (lb)	ASTM D 4632	350	≥350	50,000	100,000	3	2	3	2	572.5	484
Tear Strength (lb)	ASTM D 4533	120	≥120	50,000	100,000	3	2	3	2	235.3	162.5
Puncture Strength (lb)	ASTM D 4833	180	≥180	50,000	100,000	3	2	3	2	267.9	258.6
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: 20

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 135,000 ft^2 available for Cell 6 liner and Cell 2 final cover 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 V – Cell 6 liner construction project. Installation activities that were monitored by GeoSyntec CQA personnel included the following:

- tie-in of the 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;
- 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 future Cell 7 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 future Cell 7 liner;
- installation of the 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 RLC lines from the footprint of future VH-7 to future Cell 7 outlet;
- hydrostatic pressure and pneumatic 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-6 into Cell 6; these were monitored by CQA personnel, as described below.

As previously described in Section 3.1.3, construction of the HDPE piping system for the Cell 7 liner was incomplete at the time of preparation of this CQA final report. Additional monitoring and testing data (including hydrostatic pressure and pneumatic testing, trench backfilling, and concrete placement and associated testing) will be included in future CQA final report upon completion.

7.2 Pipe Conformance Testing and Documentation

The pipes for the Phase V 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 the Cells 6 and 7 outlets, 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 Tecumseh, 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 V 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 5.4.

- 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 outlets. 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-6 to Cell 6. 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.

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8.0 SUMMARY AND CONCLUSIONS

Construction of the OSDF Phase IV – Cell 2 final cover and Phase V – Cell 6 liner construction projects for the FCP was carried out during the period from April 2003 to January 2004. During this time, GeoSyntec provided on-site CQA personnel to monitor the construction of the two projects. As part of the CQA activities, GeoSyntec on-site CQA personnel monitored the construction and installation of the following components:

- earthwork (for Cell 2 final cover – select impacted material layer repairs, contouring layer construction, compacted clay cap construction, cover drainage layer, biointrusion barrier and choke stone layer placement, granular filter placement, vegetative soil layer construction, topsoil placement and vegetation, monitoring access construction, and riprap placement; and for Cell 6 liner – subgrade preparation, perimeter and intercell berm construction, compacted clay liner/clay wedge construction, LDS and LCS drainage layer and drainage corridor construction, and protective layer placement);

- geosynthetics (installation of GCL and GCC; Cell 2 geomembrane cap and geotextile cushion layers; Cell 6 primary liner and secondary liner geomembrane and geotextile layers; and Cell 2 erosion mat);

- leachate collection system (installation of LDS, LCS, and RLCS collection pipes and liner penetration boxes) for Cell 6;

- installation of HMW pipes for Cell 7 liner;

- tie-in of the LDS, LCS, and RLCS dual-containment pipes from VH-6 stub-outs to Cell 6 outlet; and

- partial installation of LDS, LCS, and RLCS dual-containment pipes from VH-7 footprint to future Cell 7 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 – Cell 2 final cover and Phase V – Cell 6 liner projects 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 – Cell 2 final cover and Phase V – Cell 6 liner construction projects for the OSDF were 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

4 Mar 2004

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

REFERENCES

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

GeoSyntec Consultants, "*Construction Quality Assurance Final Report, On-Site Disposal Facility, Phase I and Leachate Conveyance System*", Revision 0, Prepared for United States Department of Energy Fernald Environmental Management Project Fernald, Ohio under Fluor Daniel Fernald Subcontract 95S0005028, January 1998a, Vols. I through IX.

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GeoSyntec Consultants, "*Construction Quality Assurance Final Report, Enhanced Permanent Leachate Transmission System, On-Site Disposal Facility*", Revision 0, Prepared for United States Department of Energy Fernald Environmental Management Project Fernald, Ohio under Fluor Fernald, Inc. Subcontract 95S0005028, Oct 2001, Vols. I through V.

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GeoSyntec Consultants, *"Construction Quality Assurance Final Report, Phase III – Cell 1 Final Cover Construction, On-Site Disposal Facility"*, Revision 0, Prepared for United States Department of Energy Fernald Environmental Management Project, Fernald, Ohio under Fluor Fernald, Inc. Subcontract 95S0005028, Sept 2002, Vols. I through VI.

GeoSyntec Consultants, *"Construction Quality Assurance Final Report, Phase IV – Cells 4 and 5 Construction, On-Site Disposal Facility"*, Revision 0, Prepared for United States Department of Energy Fernald Environmental Management Project, Fernald, Ohio under Fluor Fernald, Inc. Subcontract 95S0005028, June 2003, Vols. I through VII.

APPENDIX A

CELL 6 INTERIM CONSTRUCTION CERTIFICATION LETTER

COPY

GEOSYNTEC CONSULTANTS

7400 Willey Road
Mail Stop 38
Hamilton, Ohio 45013 • USA
Tel. (513) 648-3418 • (513) 648-3417 • Fax (513) 648-3415

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11 November 2003

Mr. Thomas M. Beasley
OSDF Construction Manager
Soil and Disposal Facility Project
Fluor Fernald, Inc.
P.O. Box 538704
Cincinnati, Ohio 45253-8704

Subject: Interim Construction Certification
Phase V - Cell 6 Liner System Construction Project
On-Site Disposal Facility (OSDF)
Fernald Closure Project, Fernald, Ohio

Dear Mr. Beasley:

GeoSyntec Consultants (GeoSyntec) provided construction quality assurance (CQA) and construction quality control (CQC) services during the OSDF Phase V- Cell 6 liner system construction project at the Fernald Closure Project (FCP) site. The purpose of this letter is to document that, based on the CQA and CQC activities performed by GeoSyntec, construction of the Cell 6 liner system is substantially complete.

GeoSyntec CQC personnel provided monitoring, testing, and documentation services during construction and/or installation of the soils and geosynthetics components of the Cell 6 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, monitoring 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 include CQC documentation and as-built drawings on the construction of the Phase V – Cell 6 liner system construction project. The final certification report, which will include documentation on the placement of the impacted protective layer component of the Cell 6 liner system, will be submitted at the end of the construction season.

RECYCLED AND RECYCLABLE

Based on the observations and documentation, the OSDF Cell 6 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 OSDF design process. On the basis of our observations and testing, it is anticipated that Cell 6 is ready to begin receiving impacted material meeting the OSDF waste acceptance criteria (WAC).

Should you have any questions on this letter, please do not hesitate to contact the undersignd.

Sincerely,

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

Copies to:
J.D. Chiou, Ph.D., P.E., Fluor Fernald, Inc.
Uday Kumthekar, P.E., Fluor Fernald, Inc.
Charles C. VanArsdale, P.E., Fluor Fernald, Inc.
Reinhard Friske, Fluor Fernald, Inc.
Donald B. Goetz, Fluor Fernald, Inc.
Collin Sukow, GeoSyntec CQC

APPENDIX B

PHOTOGRAPHIC DOCUMENTATION

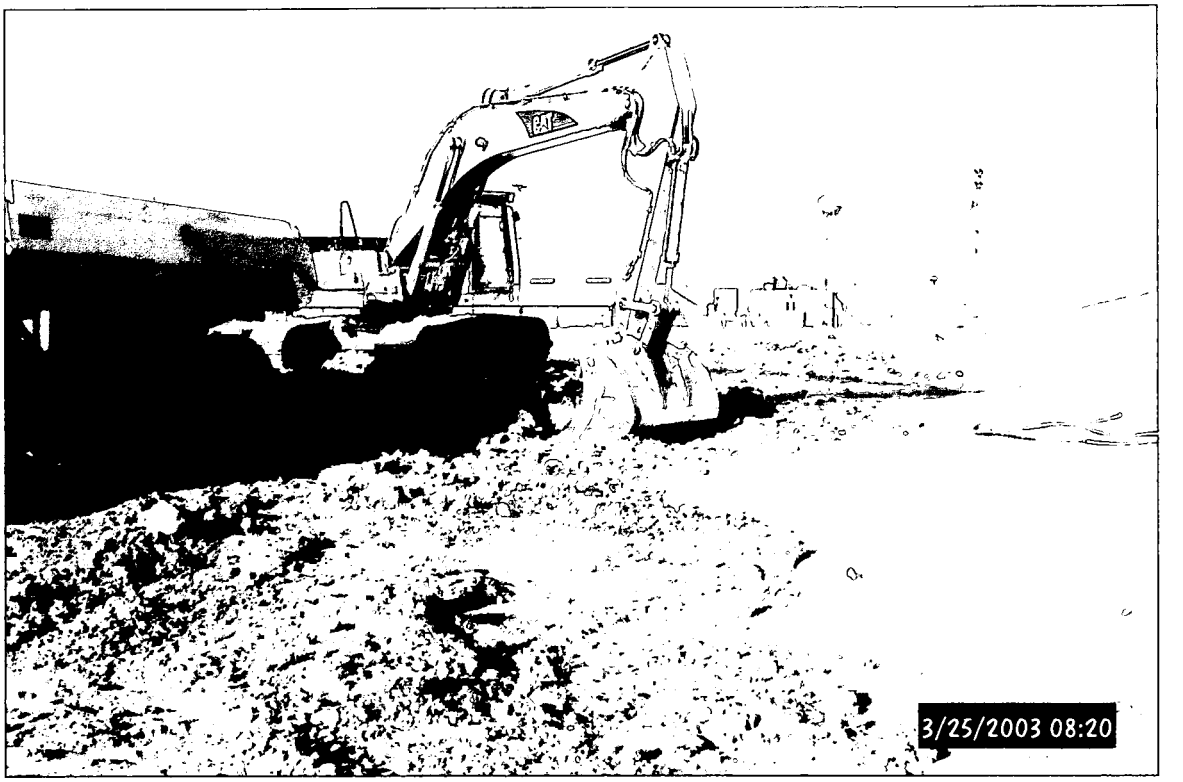

Photo # 1. Subgrade preparation in Cell 6.

Photo # 2. Excavation of the Cell 1 cap termination exposing the existing clay liner for tie-in to Cell 2.

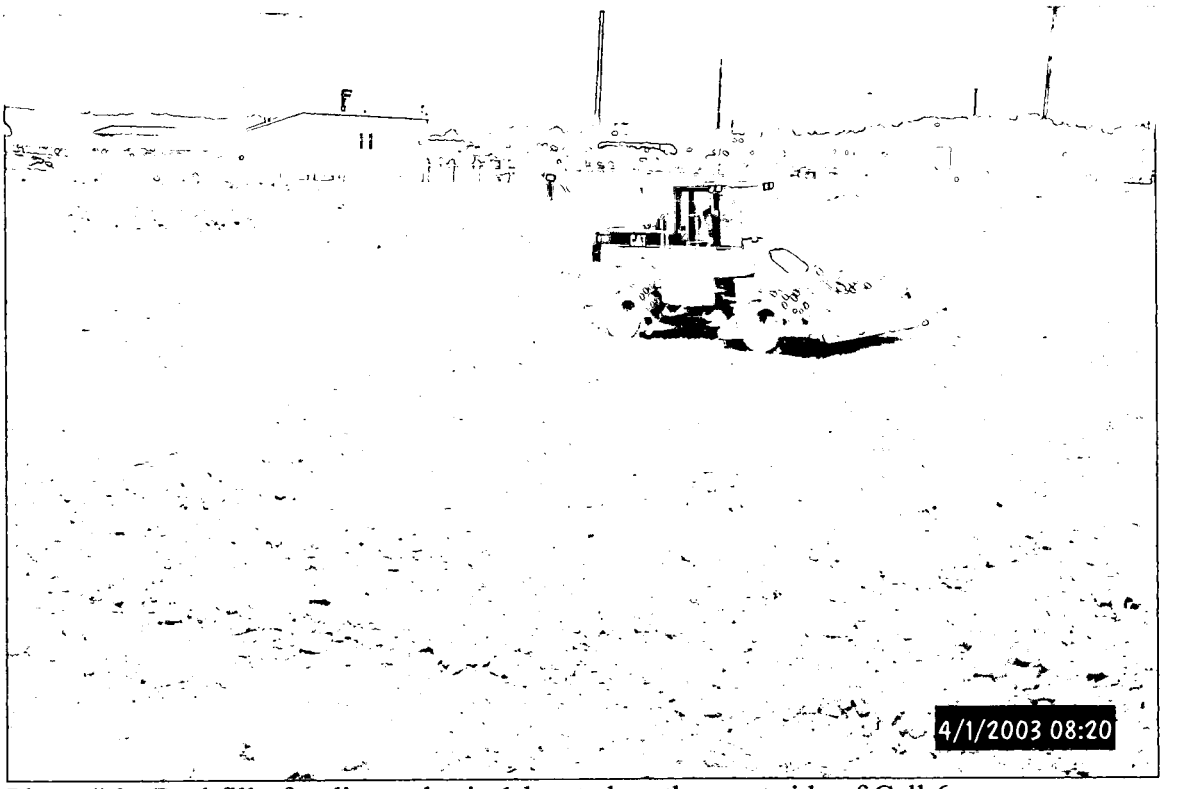

Photo # 3. Backfill of sediment basin 1 located on the west side of Cell 6.

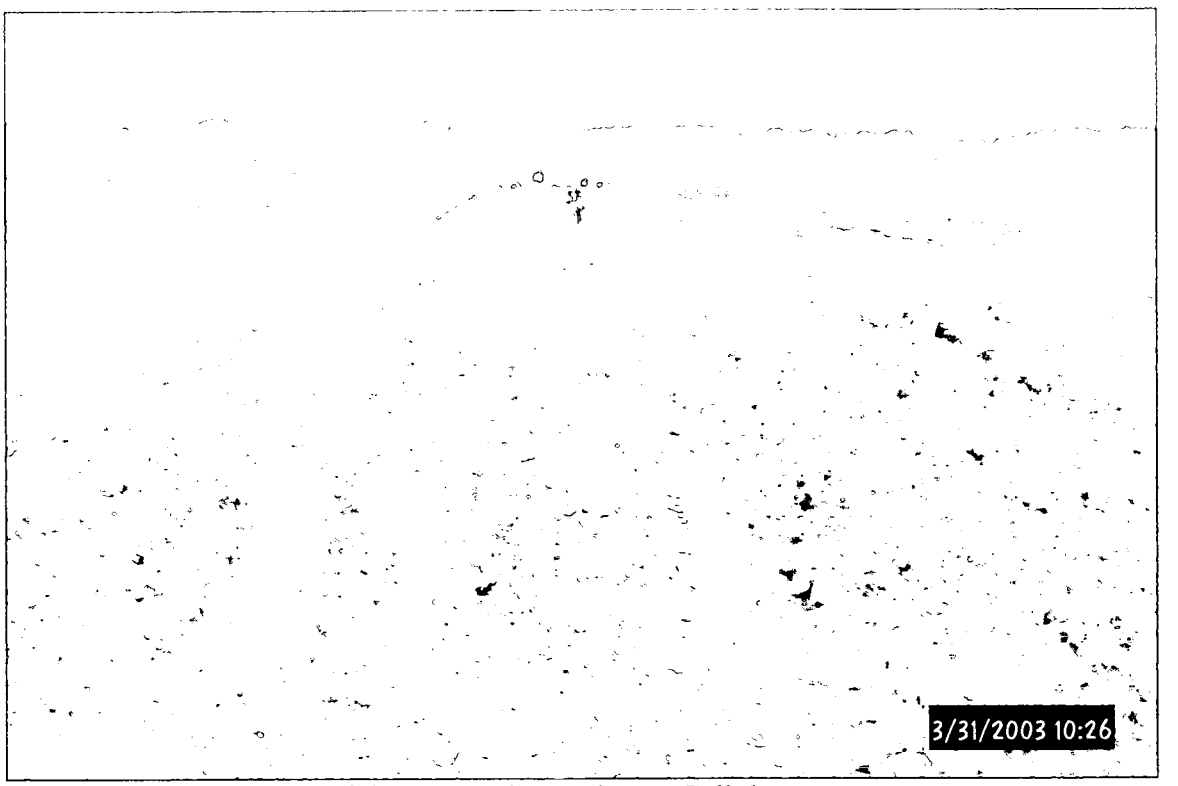

Photo # 4. Construction of the east perimeter berm, Cell 6.

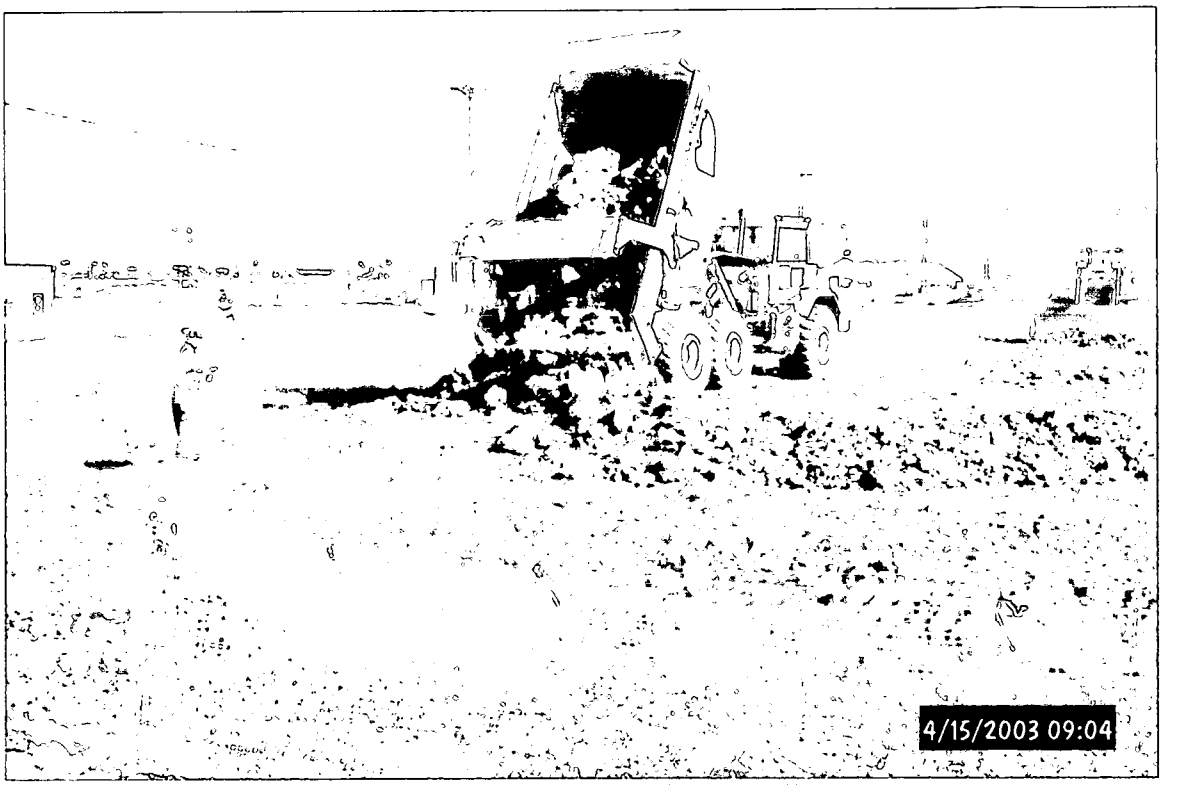

Photo # 5. Placement of fill for the west perimeter berm, Cell 6.

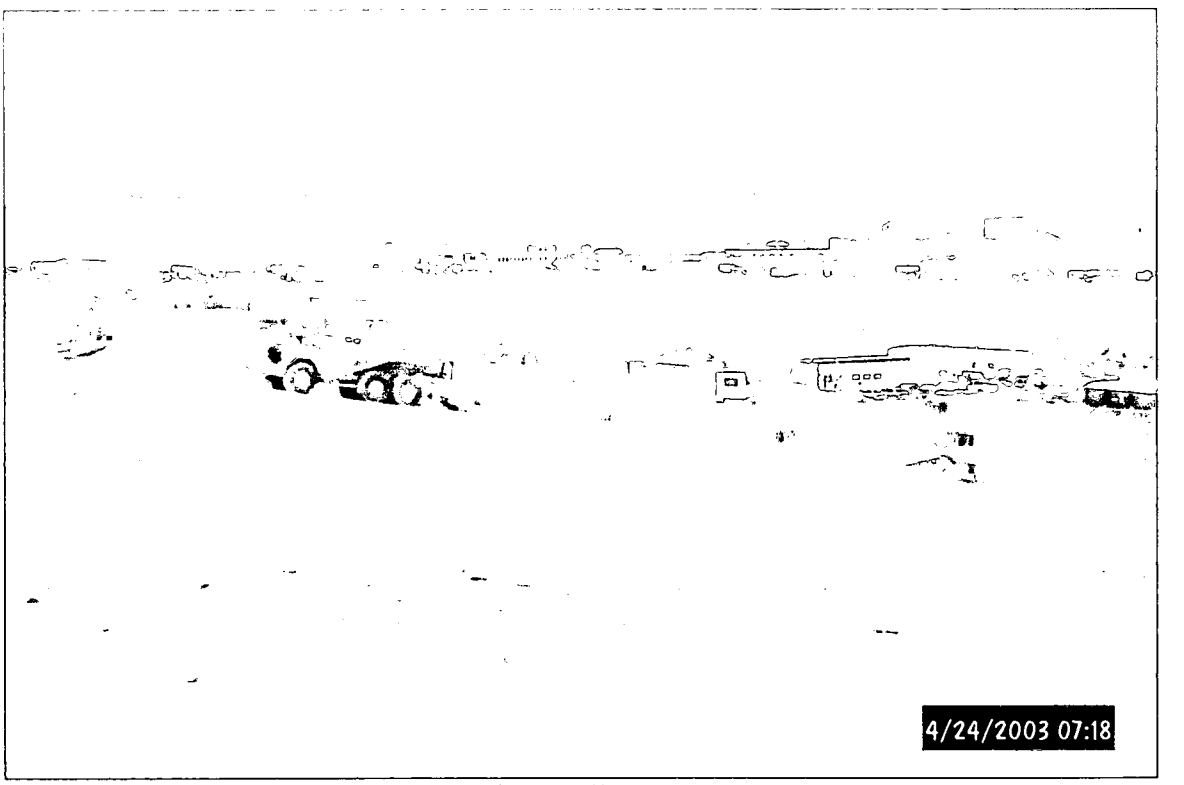

Photo # 6. Contouring layer construction, Cell 2 Cap.

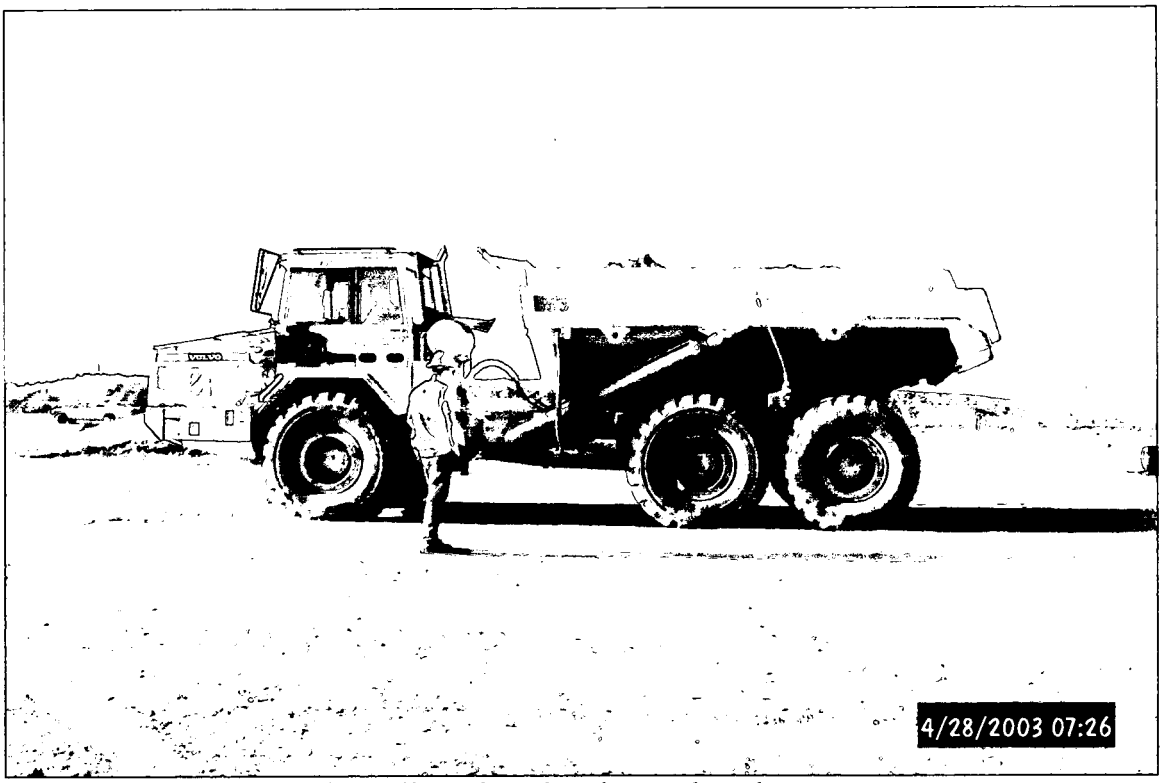

Photo # 7. Proofrolling the Cell 6 subgrade prior to clay placement.

Photo # 8. Rock bridge placement of a soft area undercut on the floor of Cell 6.

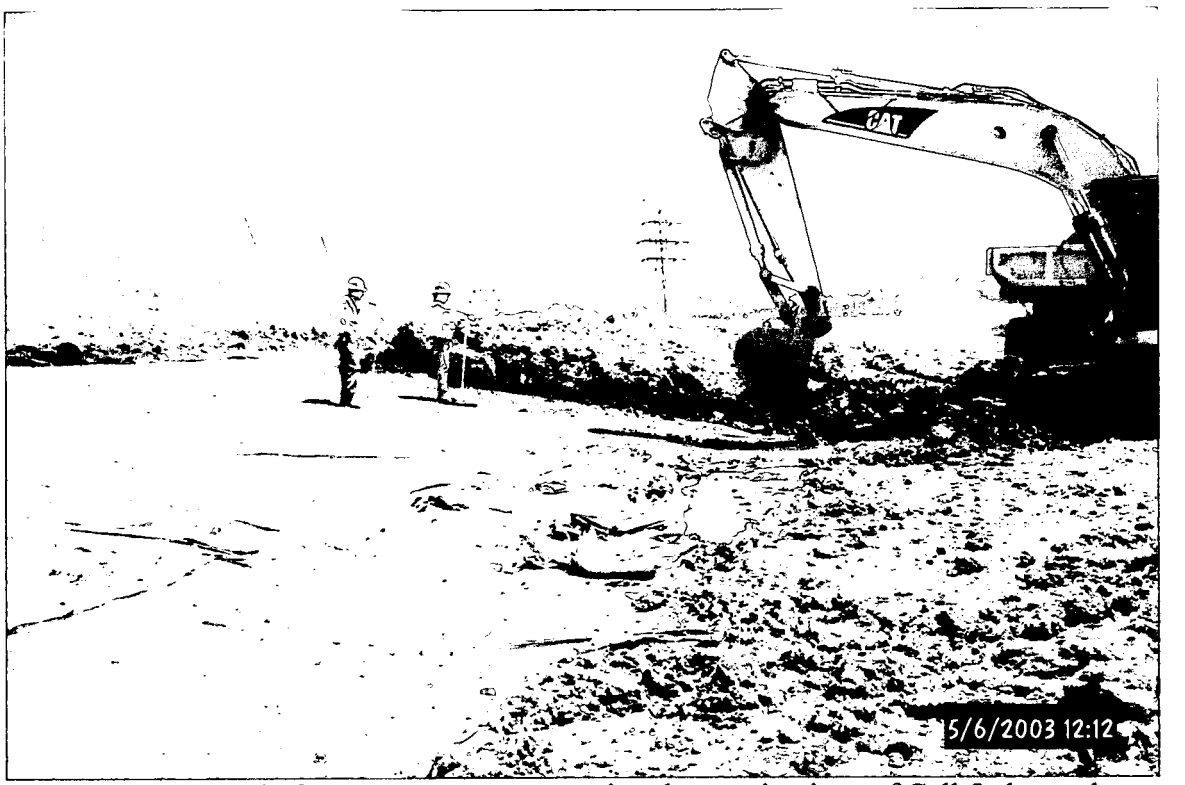

Photo # 9. Removal of temporary cover exposing the terminations of Cell 5 clay and synthetic liners for tie-in to Cell 6.

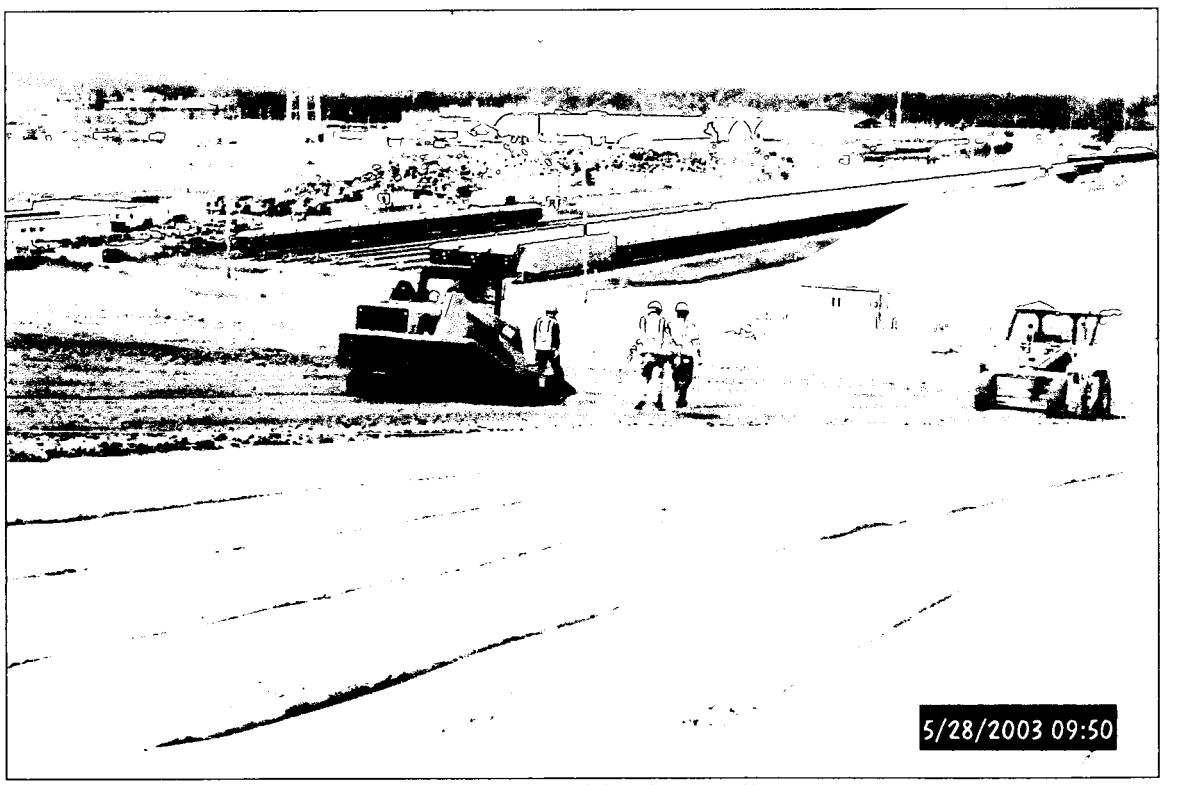

Photo # 10. Rock picking and clay liner stabilization, Cell 2 Cap.

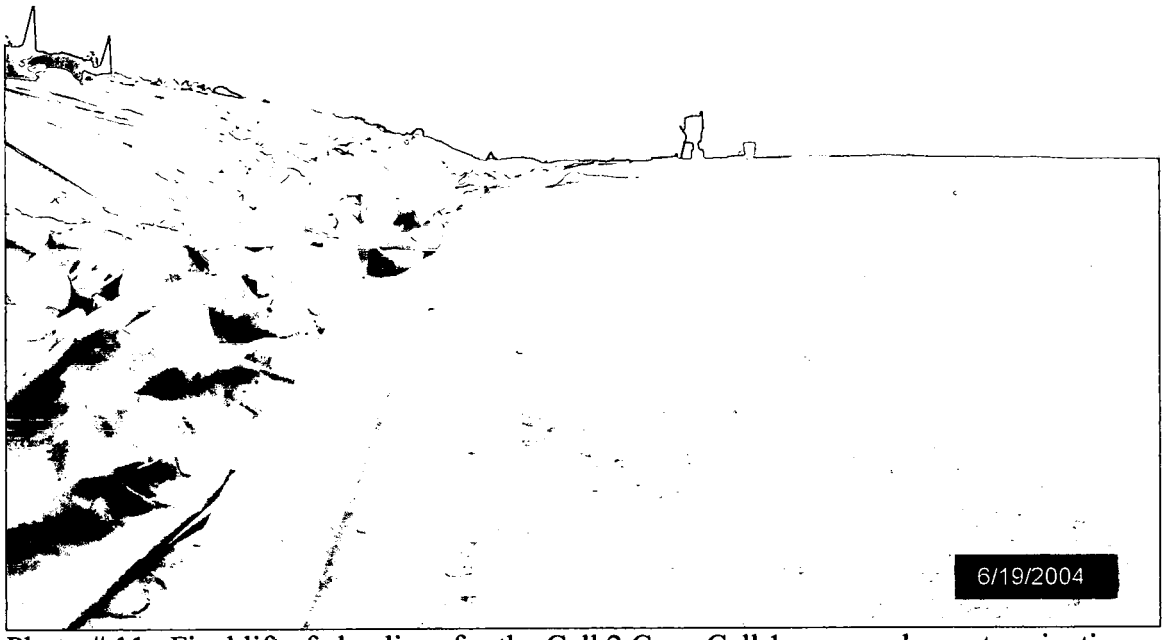

Photo # 11. Final lift of clay liner for the Cell 2 Cap. Cell 1 geomembrane termination exposed for tie-in.

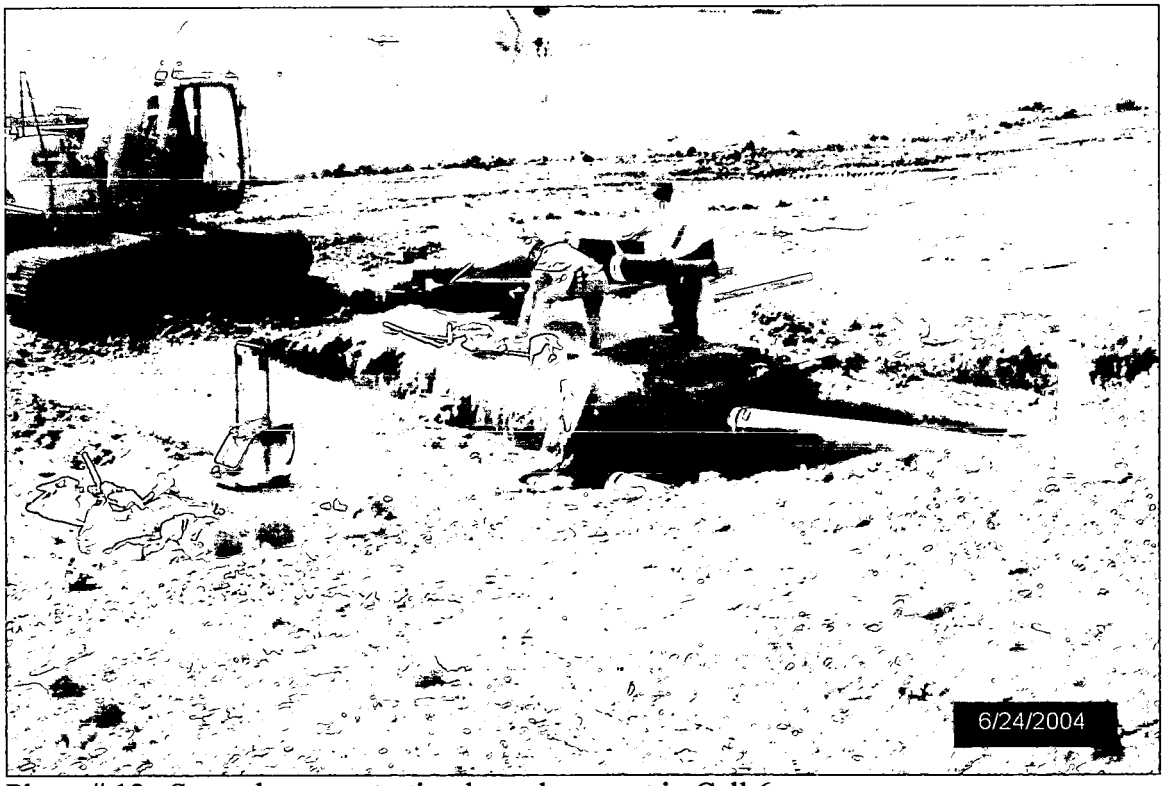

Photo # 12. Secondary penetration box placement in Cell 6.

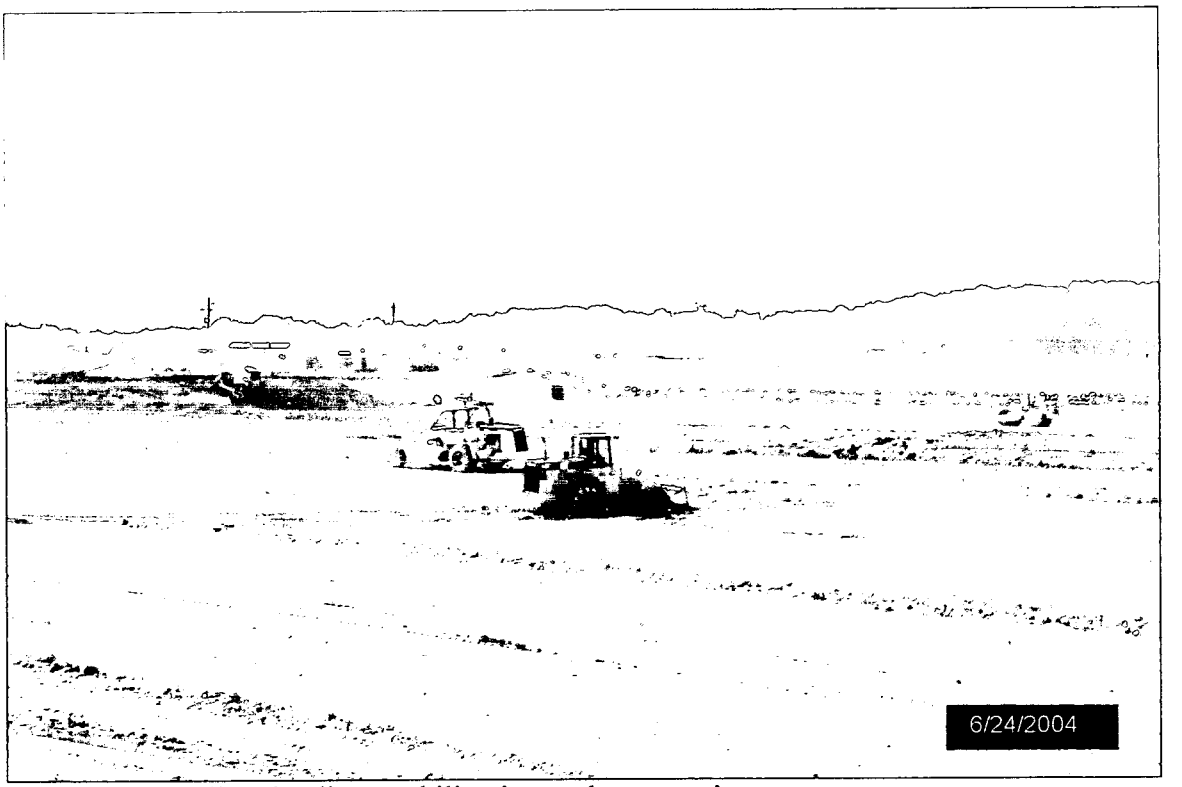

Photo # 13. Cell 6 clay liner stabilization and compaction.

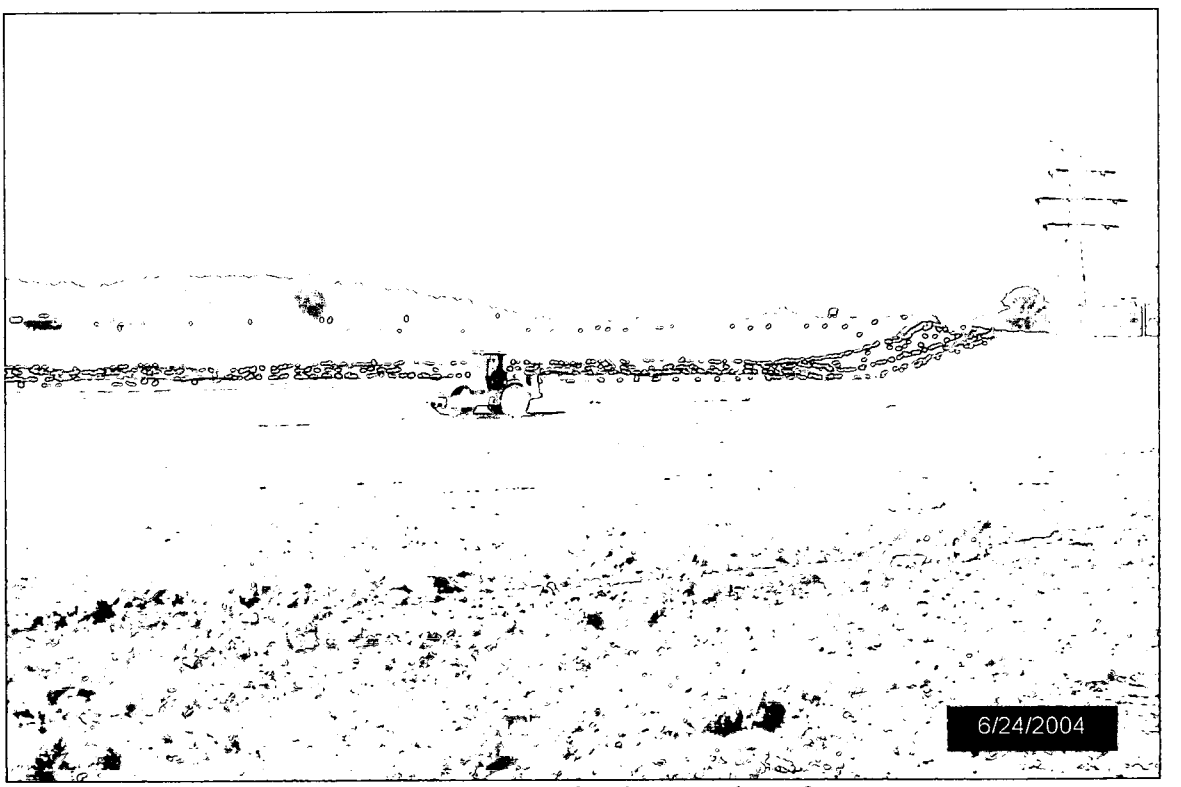

Photo # 14. Sealing the clay liner in Cell 6 for the retention of water content.

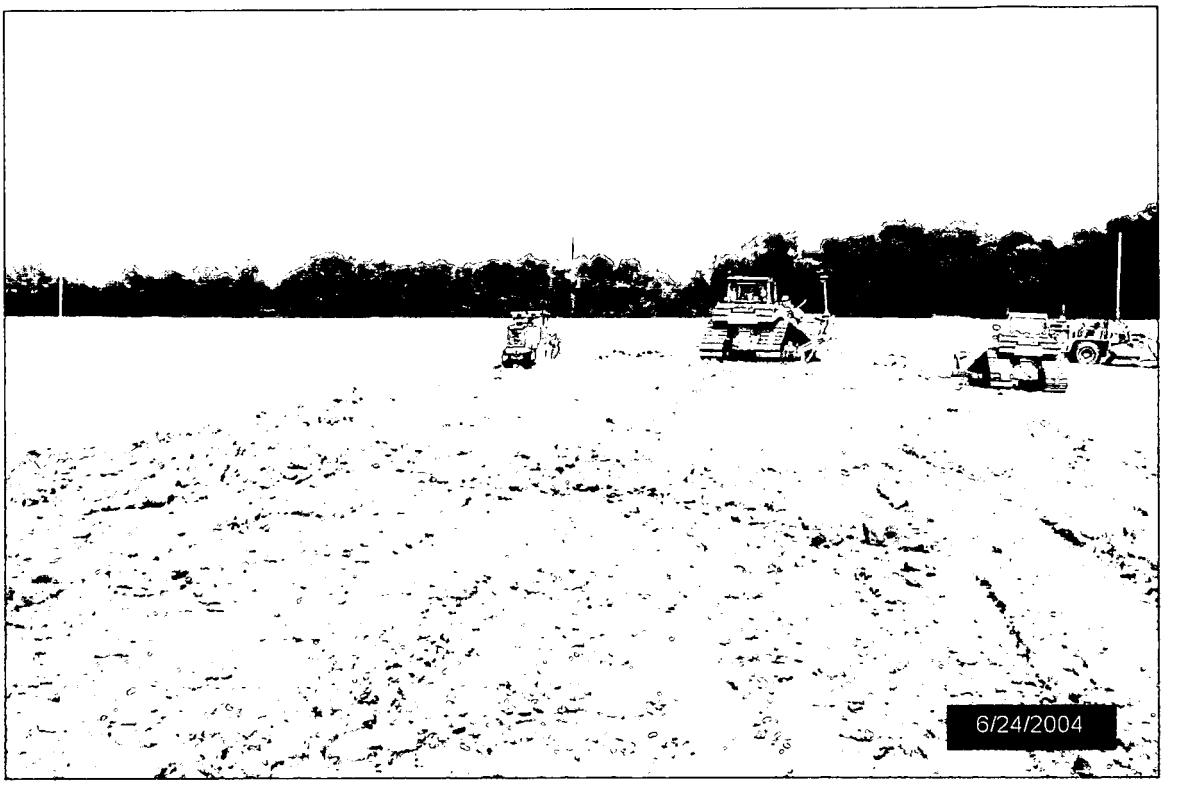

Photo # 15. Construction of the intercell berm, Cell 6.

Photo # 16. HDPE pipe welding preparation.

Photo # 17. HDPE pipe welding preparation for Cell 6 LCS line.

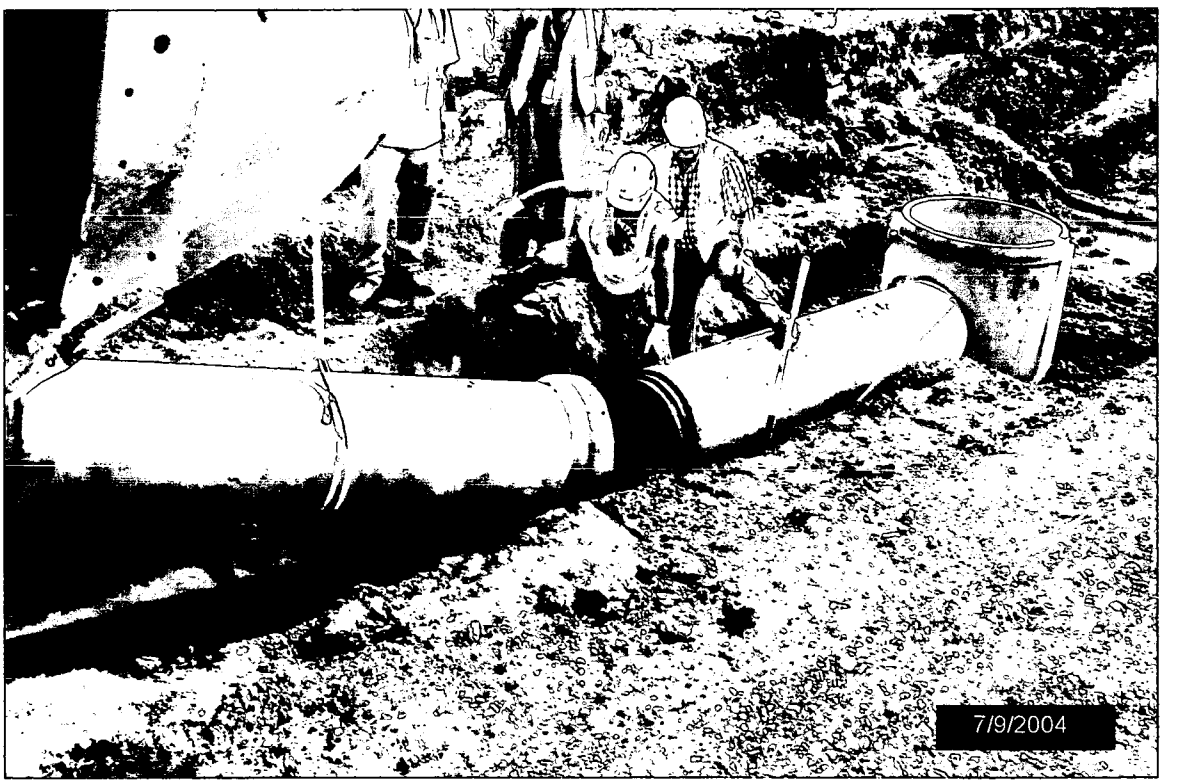

Photo # 18. Gravity Inlet Structure (GIS) construction north of Valve House 6.

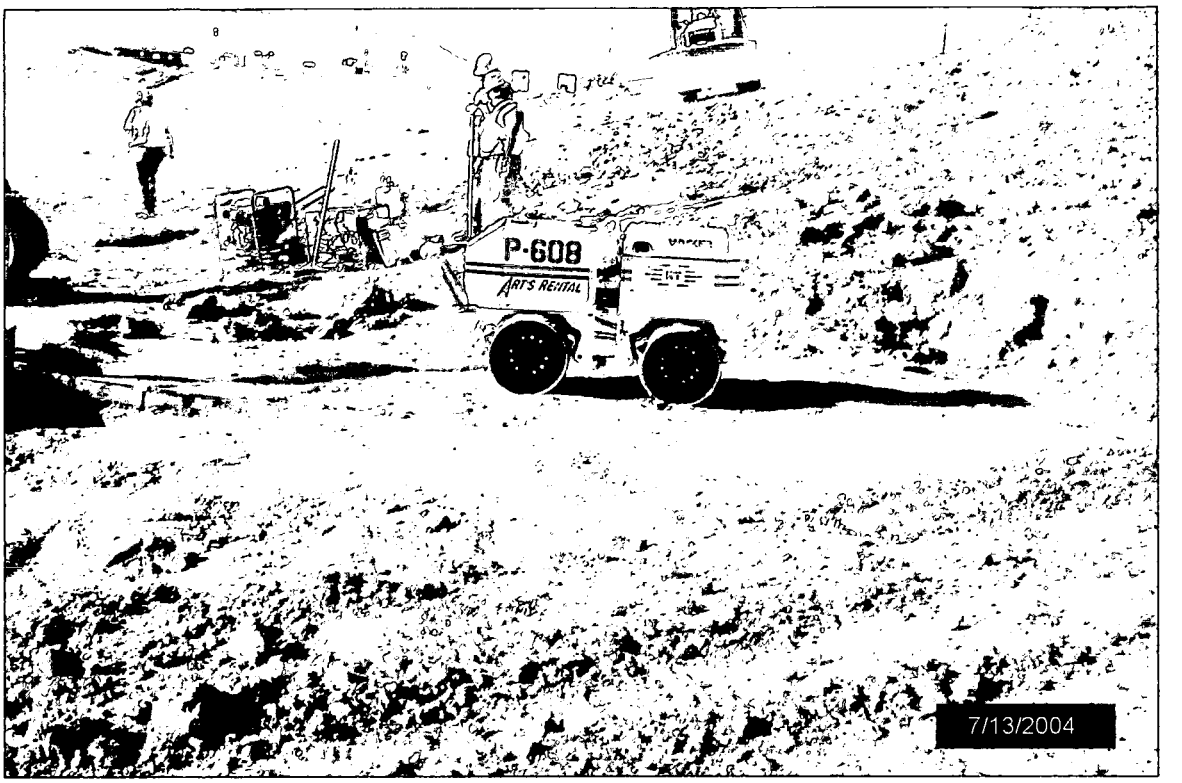

Photo # 19. Compacted fill over the Cell 6 leachate line tie-ins.

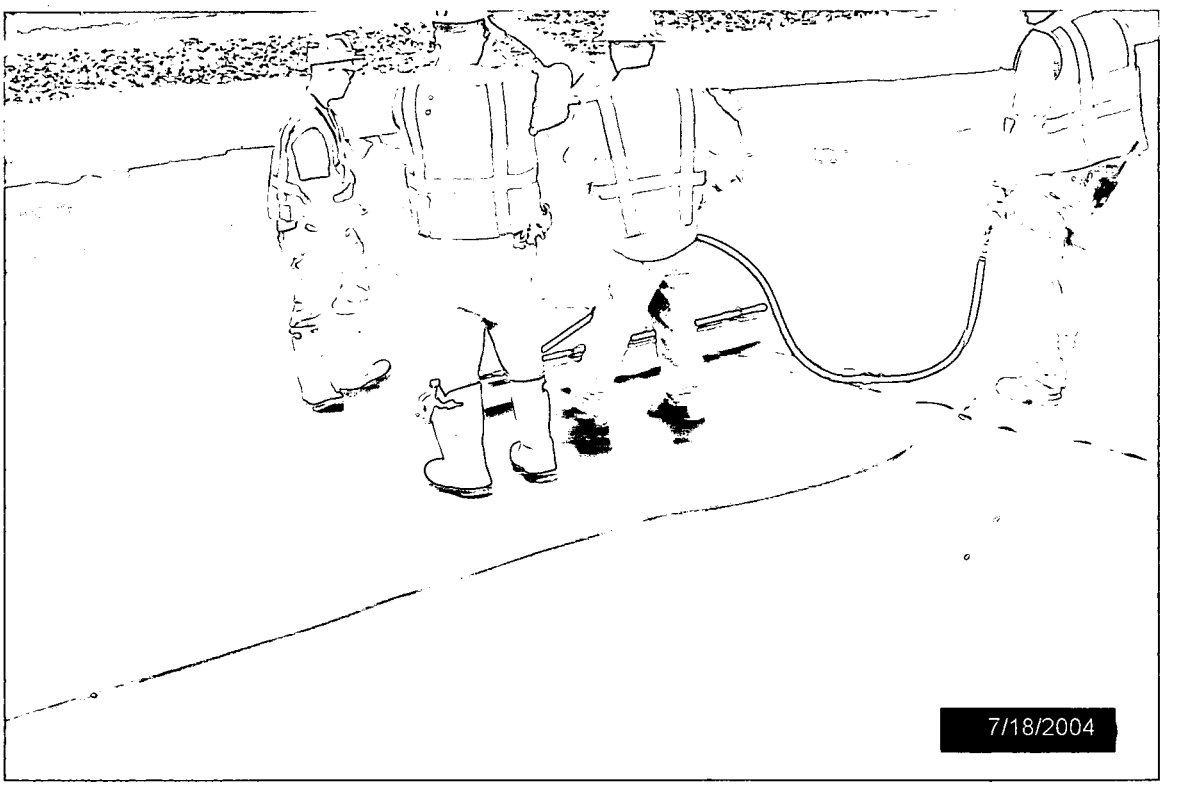

Photo # 20. Leak detection of the Cell 2 Cap geomembrane.

Photo # 21. Geotextile deployment over completed geomembrane, Cell 2 Cap.

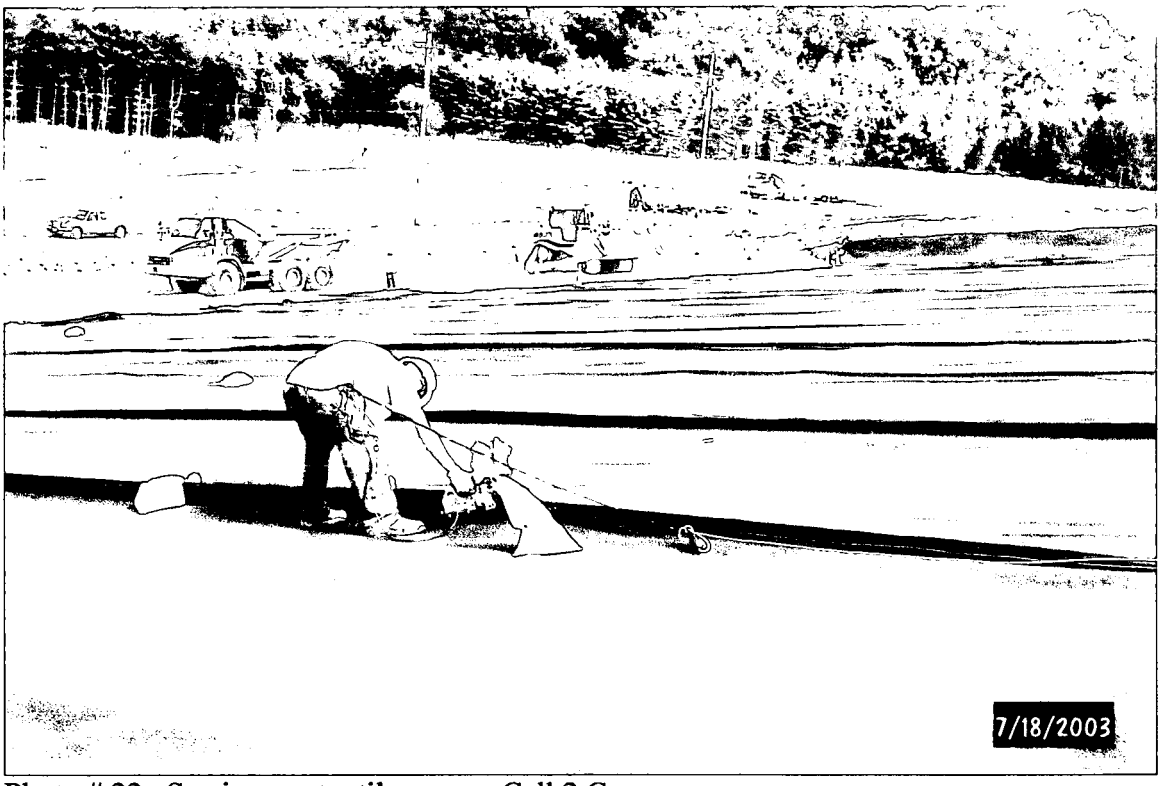

Photo # 22. Sewing geotextile seams, Cell 2 Cap.

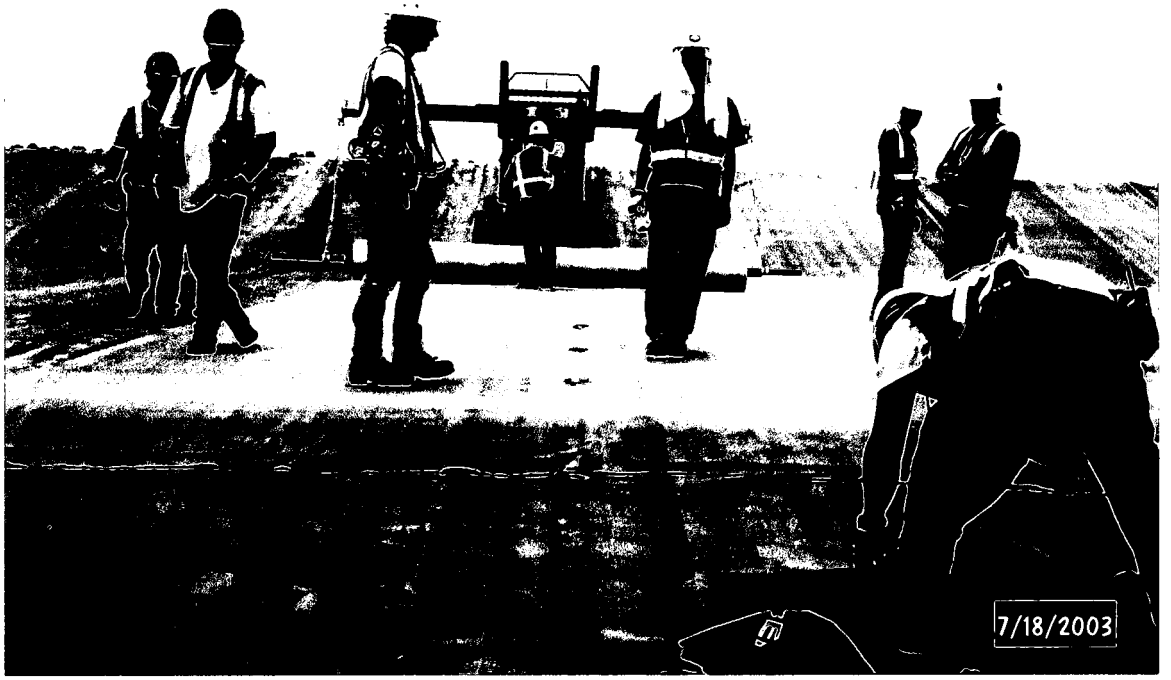

Photo # 23. Geosynthetic Clay Liner (GCL) deployment, Cell 6.

Photo # 24. Geomembrane Liner (GML) deployment, Cell 6.

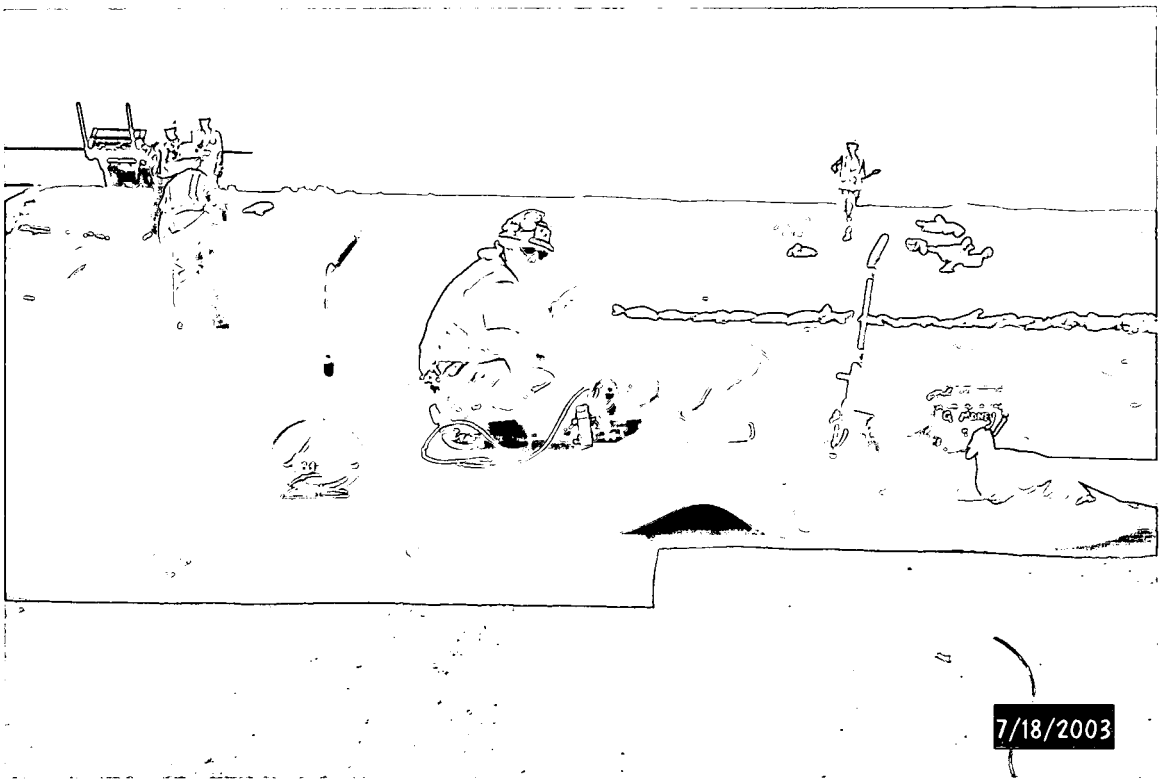

Photo # 25. Fusion welding GML panels, Cell 6.

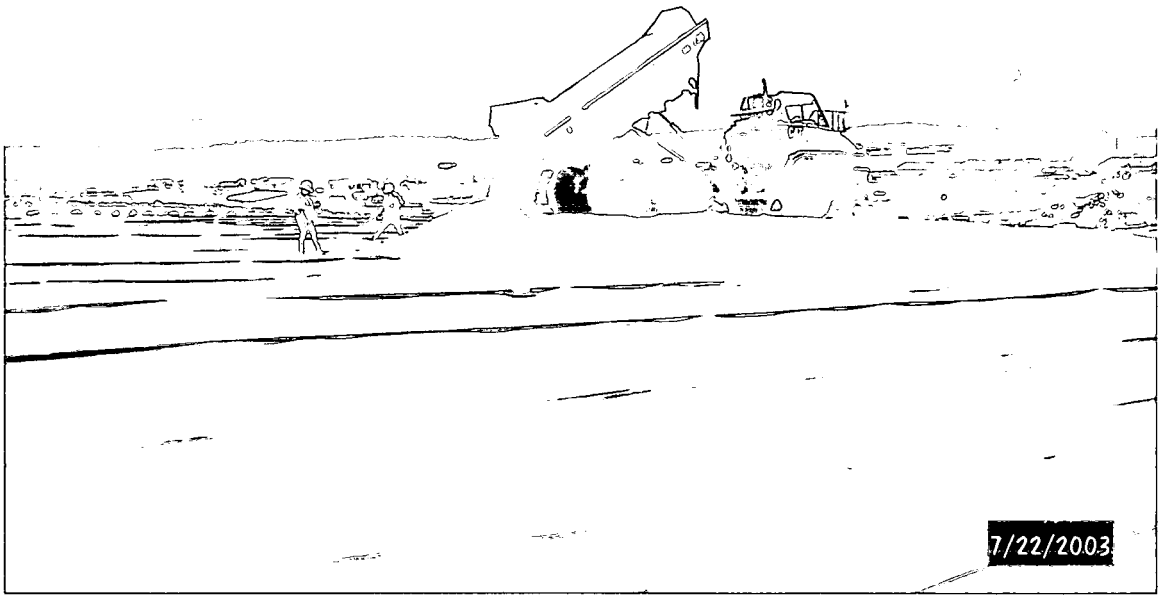

Photo # 26. Placement of cover drainage layer on top of the Cell 2 Cap.

Photo # 27. East side of the Cell 2 Cap. Geotextile deployment complete, Cell 1 upper layers in the background.

Photo # 28. Top of Cell 2 Cap. Geomembrane, geotextile, and cover drainage layer.

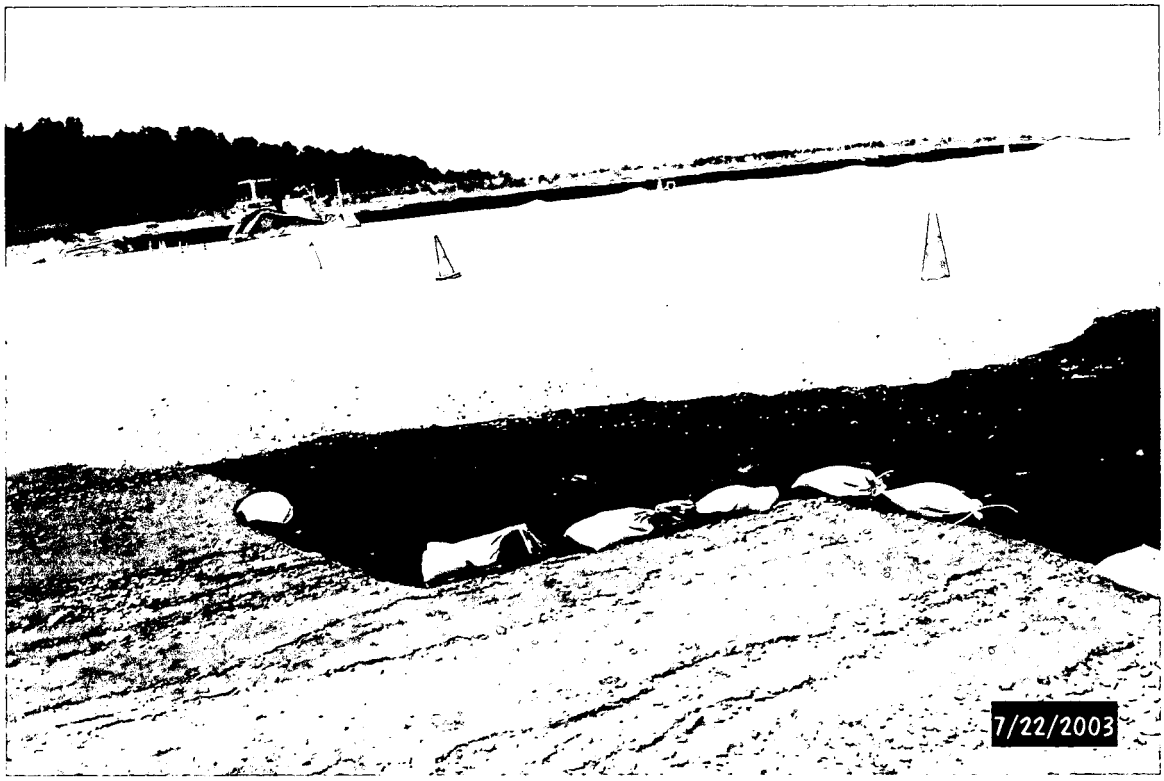

Photo # 29. Stone placement for the Cell 2 Cap.

Photo # 30. Cell 6 inner cell berm GCL and GML deployment.

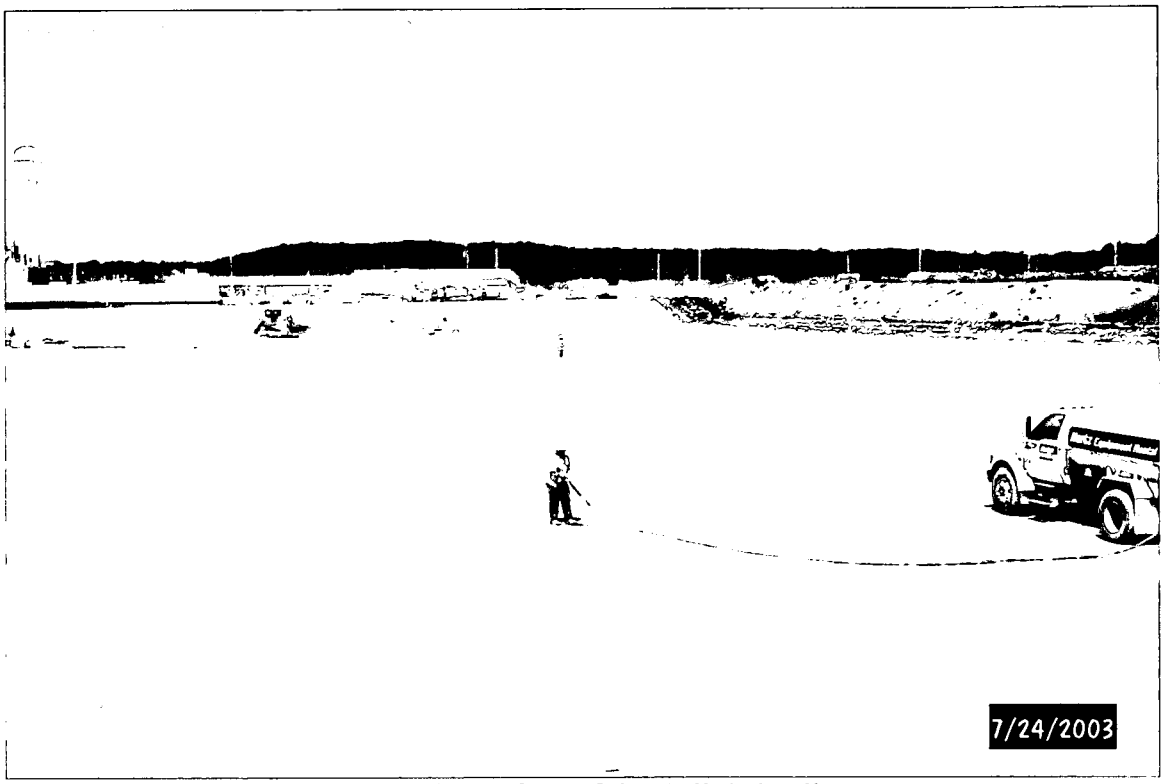

Photo # 31. Water conditioning the surface of the Cell 6 clay liner.

Photo # 32. Extrusion welding GML in Cell 6.

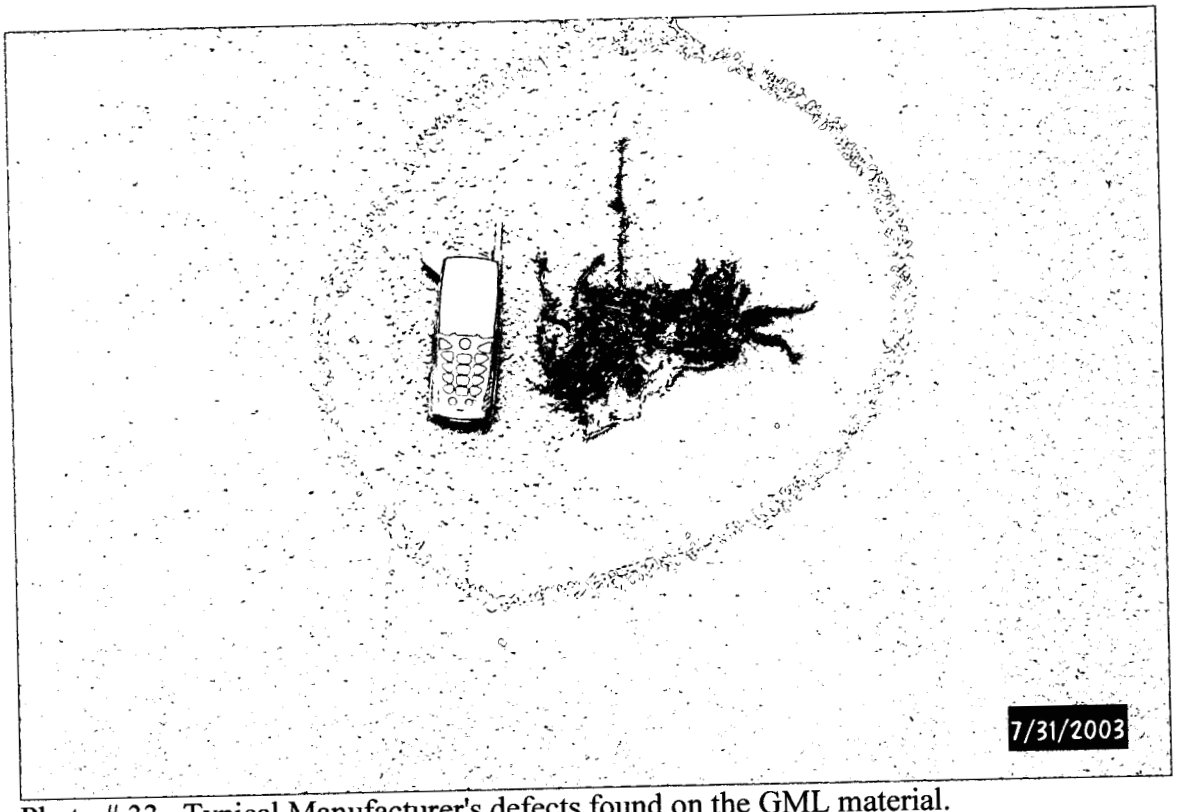

Photo # 33. Typical Manufacturer's defects found on the GML material.

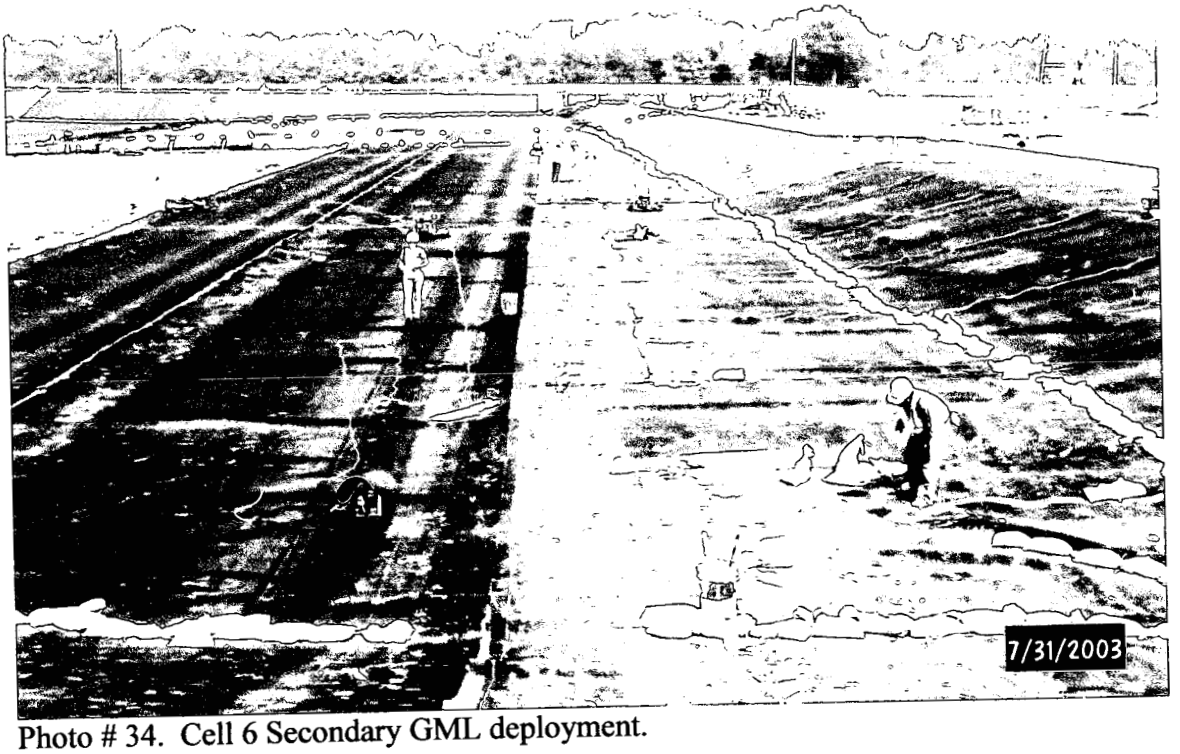

Photo # 34. Cell 6 Secondary GML deployment.

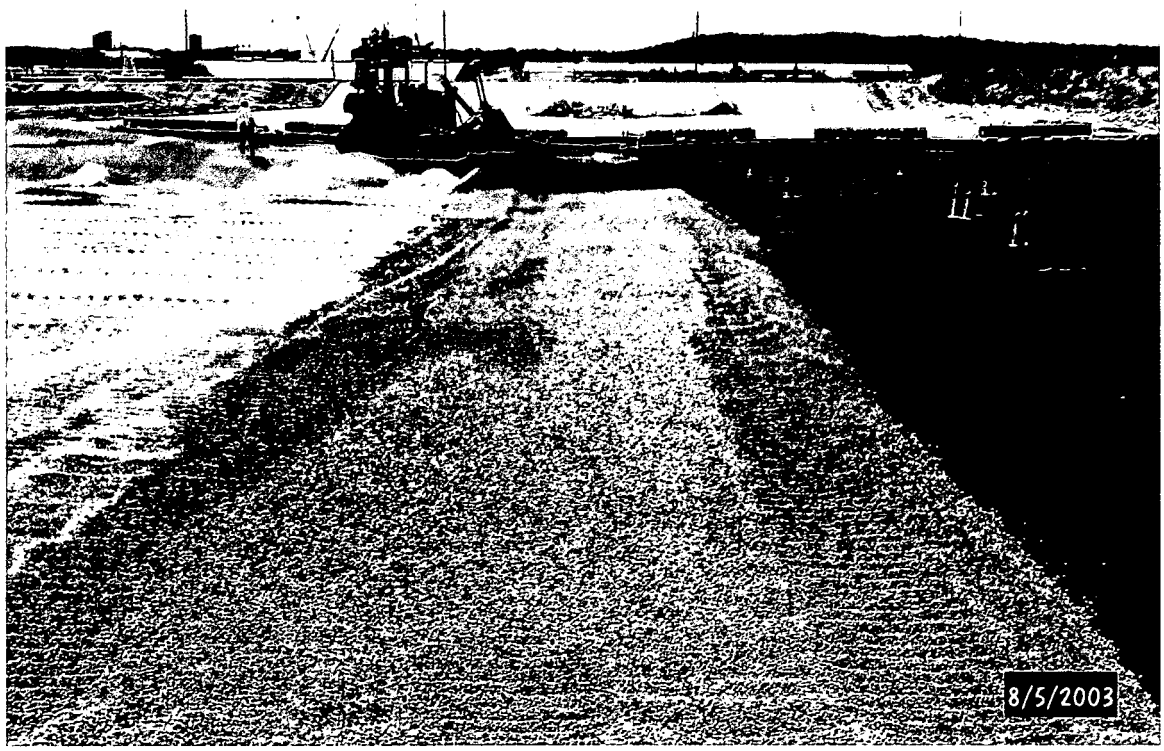

Photo # 35. Placement of # 57 stone in the drainage corridor over the Secondary GML, Cell 6.

Photo # 36. Placement of biointrusion barrier (Type D Riprap), Cell 2 Cap.

Photo # 37. Drainage sand placement over the choke stone and biointrusion barrier, Cell 2 Cap.

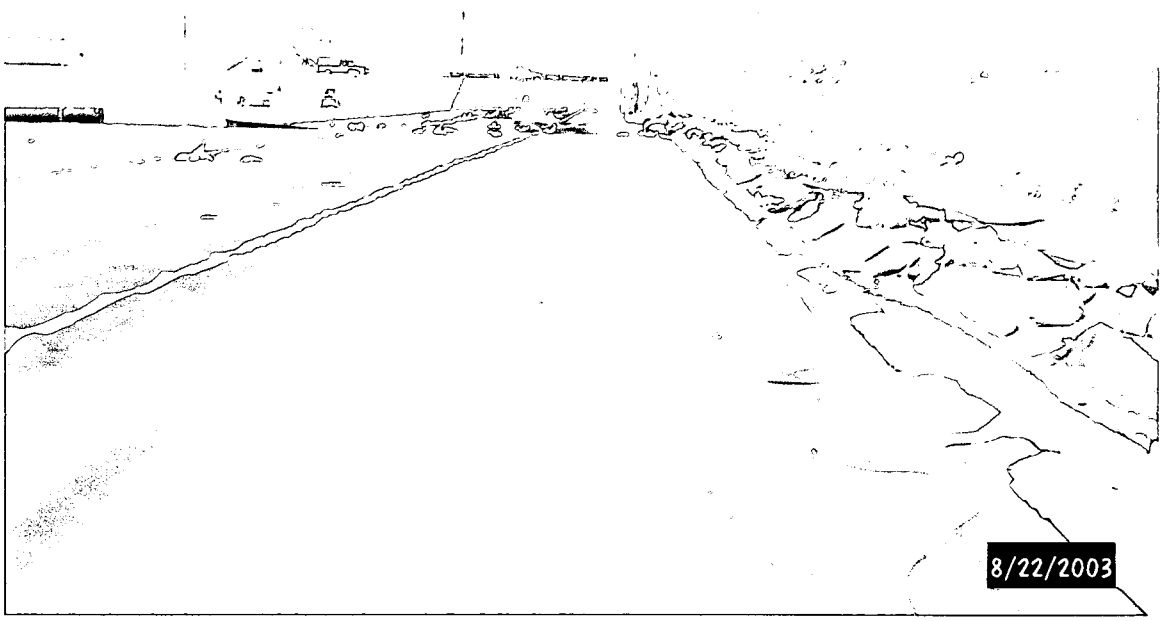

Photo # 38. GML deployment along the Cell 5 and Cell 6 tie-in.

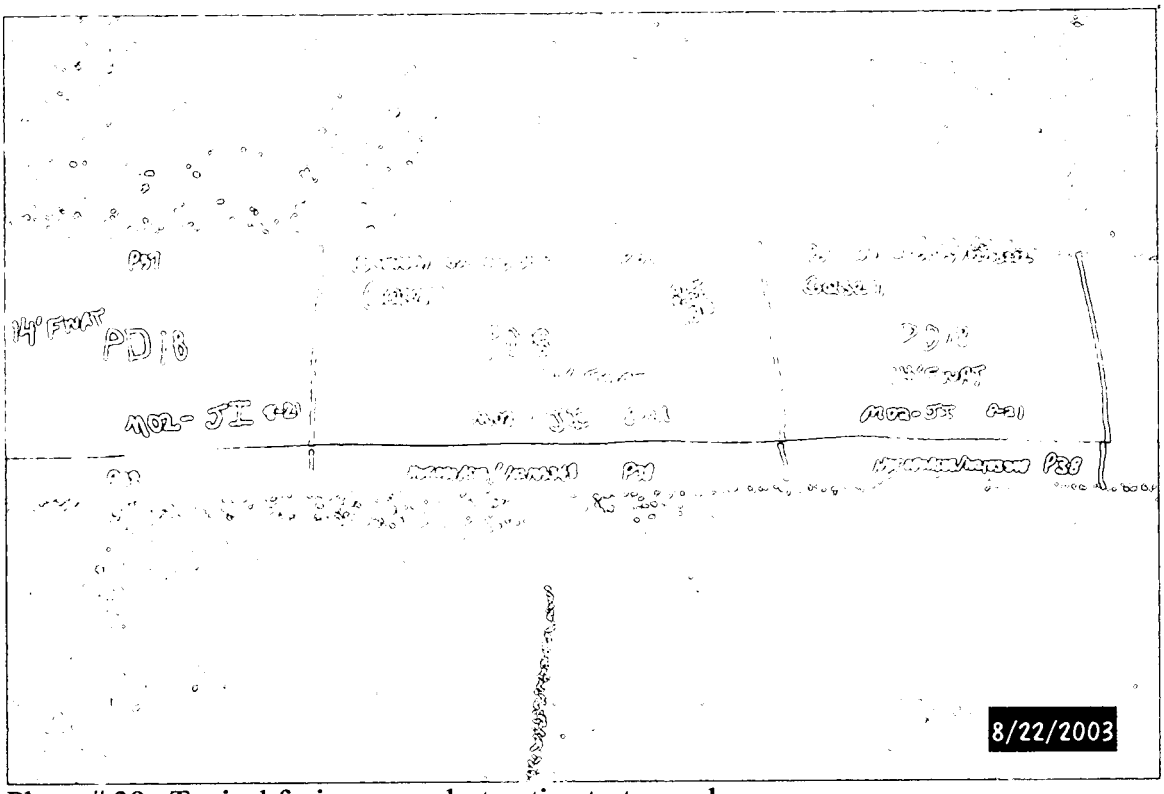

Photo # 39. Typical fusion seam destructive test sample.

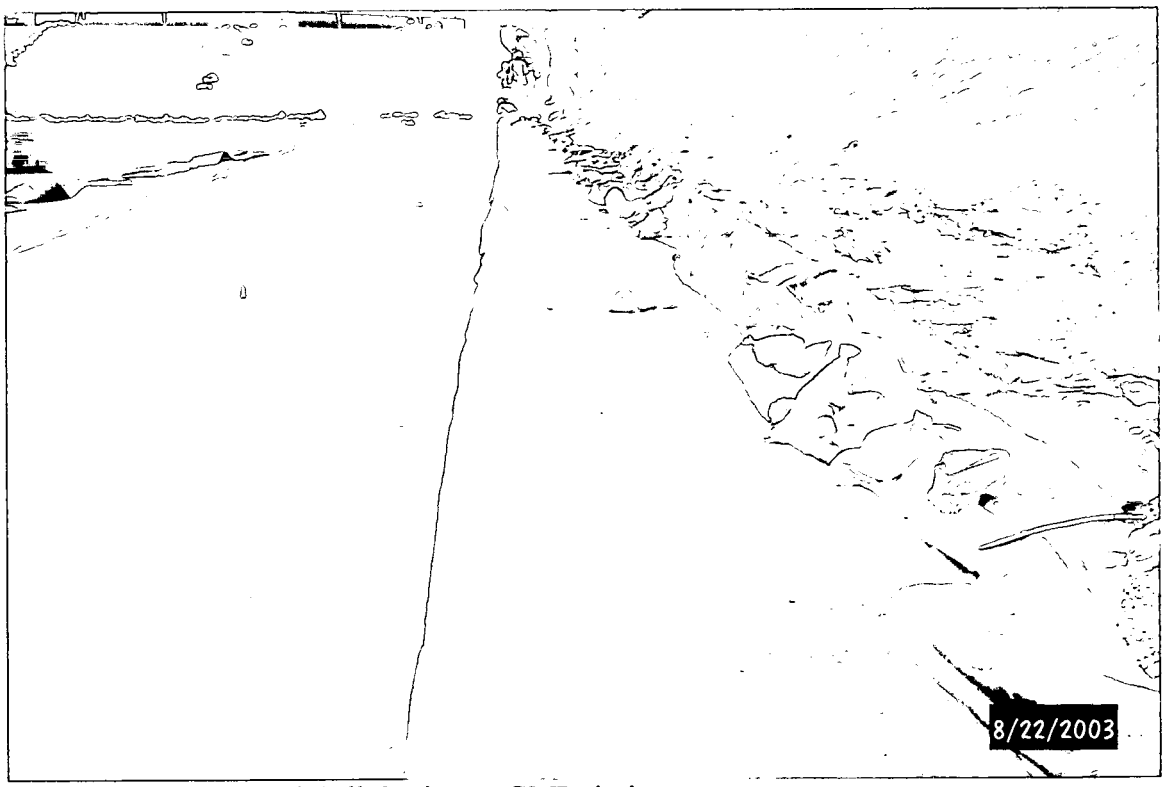

Photo # 40. Cell 5 and Cell 6 primary GML tie-in.

Photo # 41. Vacuum testing on a penetration box in Cell 6.

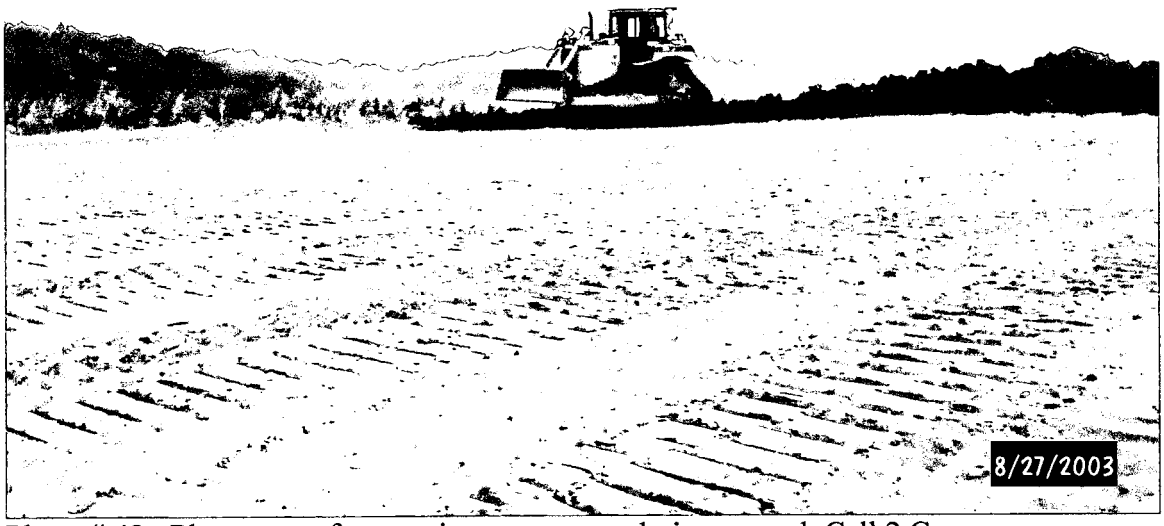

Photo # 42. Placement of vegetative cover over drainage sand, Cell 2 Cap.

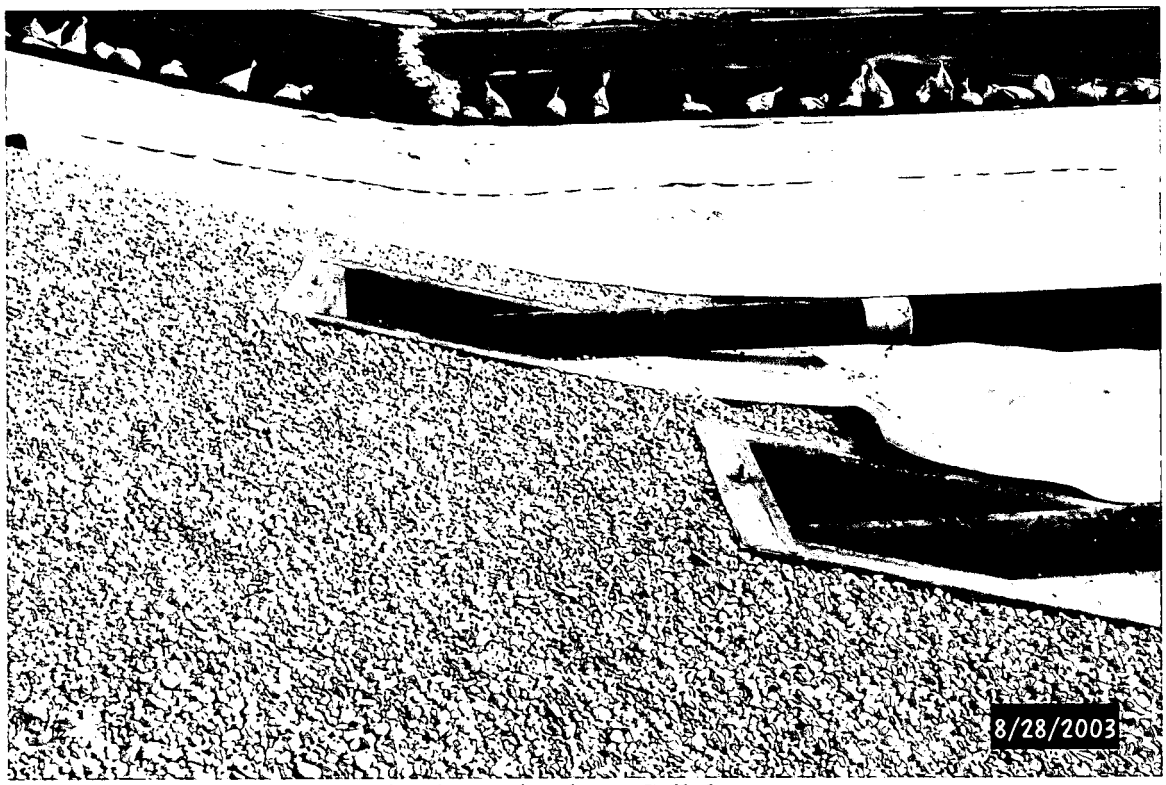

Photo # 43. Primary penetration boxes in place, Cell 6.

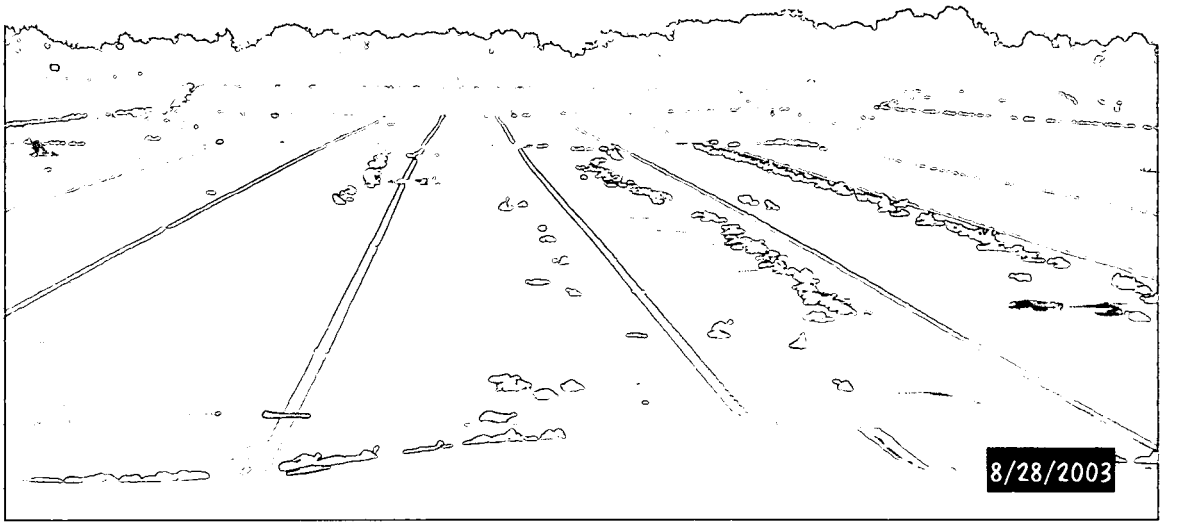

Photo # 44. Cell 6 primary liner.

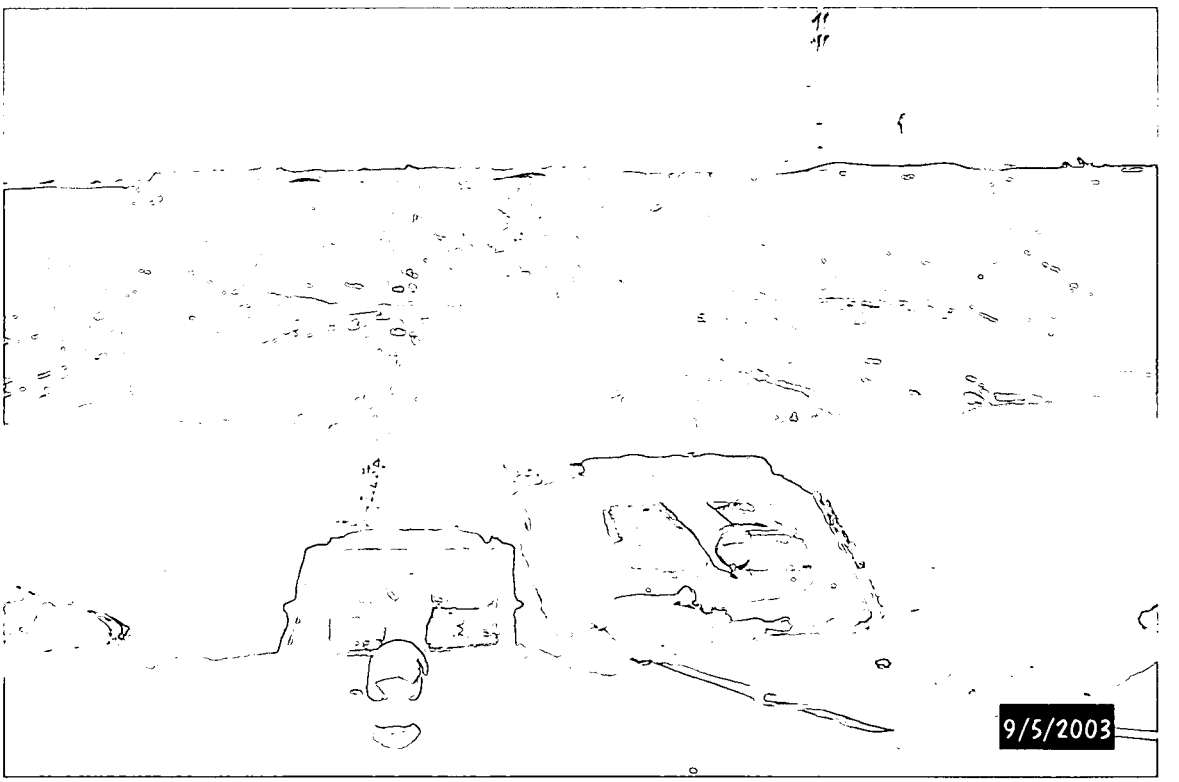

Photo # 45. Primary penetration boxes, Cell 6.

Photo # 46. Vacuum box testing GML in Cell 6.

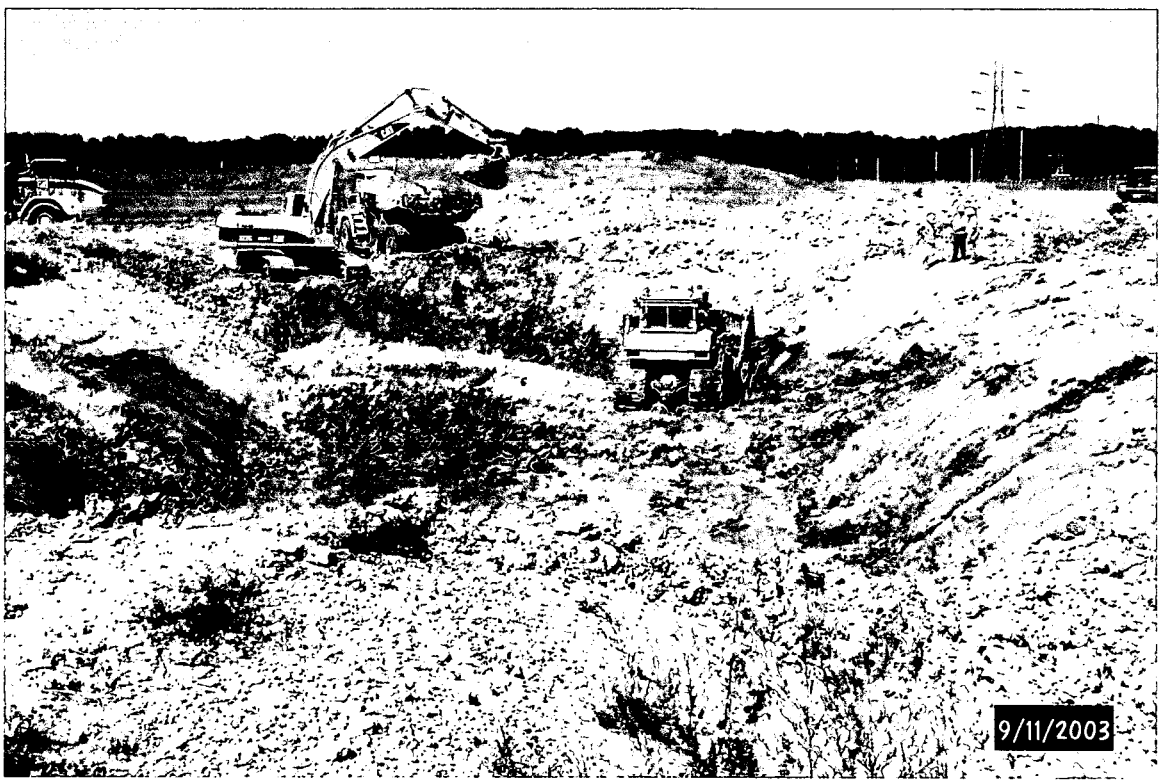

Photo # 47. Removal of sediment from sediment basin prior to backfilling.

Photo # 48. Clay screening in the south field borrow area.

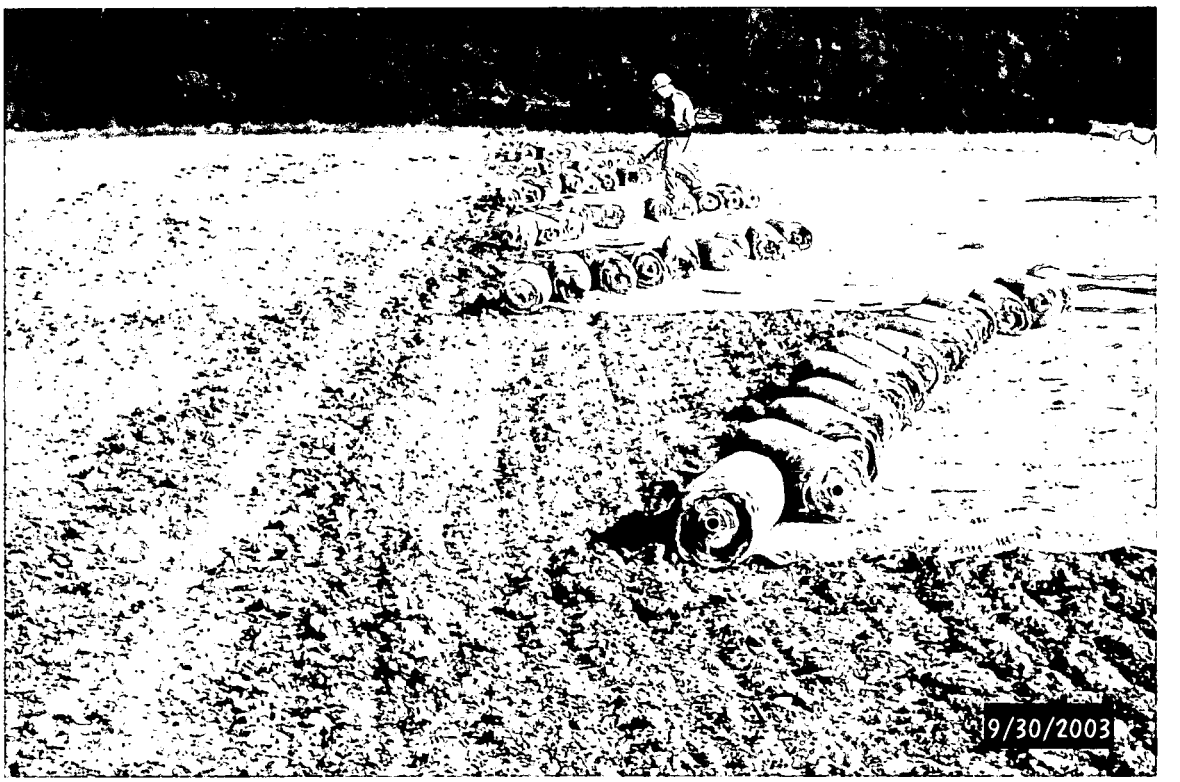

Photo # 49. Placement of erosion matting over topsoil on the Cell 2 Cap.

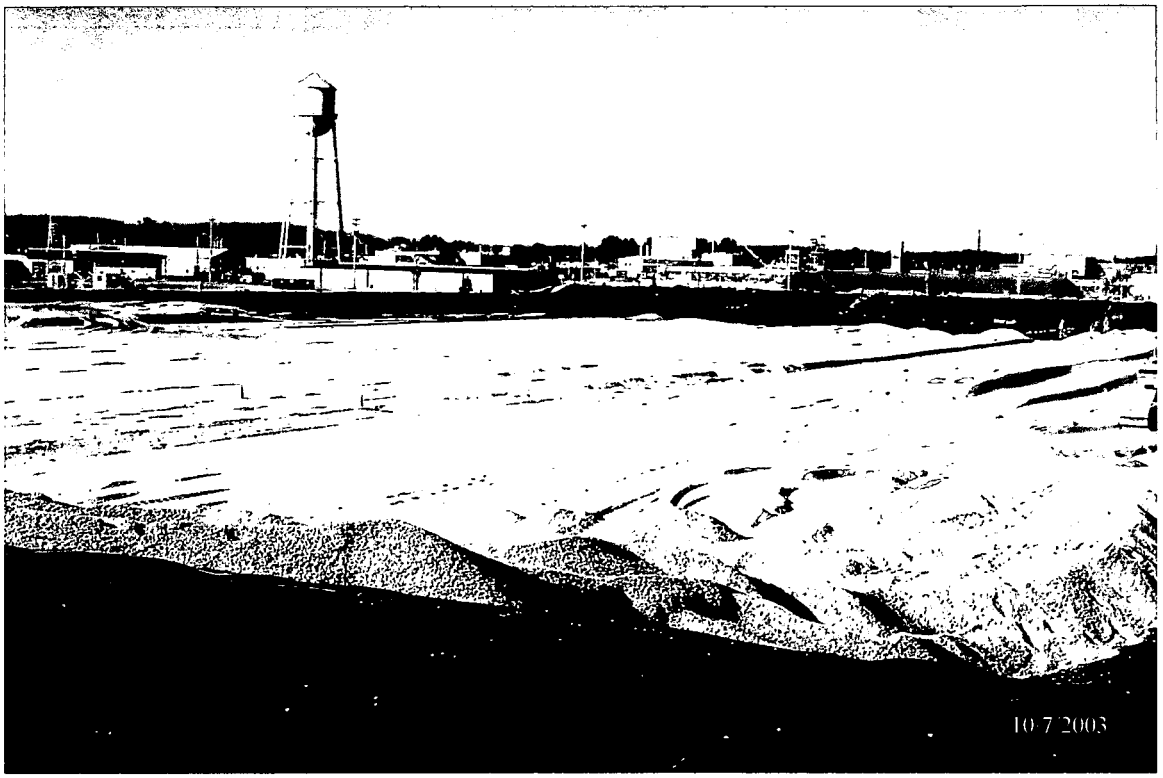

Photo # 50. Drainage stone placement over the primary GML, Cell 6.

Photo # 51. Geotextile sewn through the west anchor trench over the primary GML.

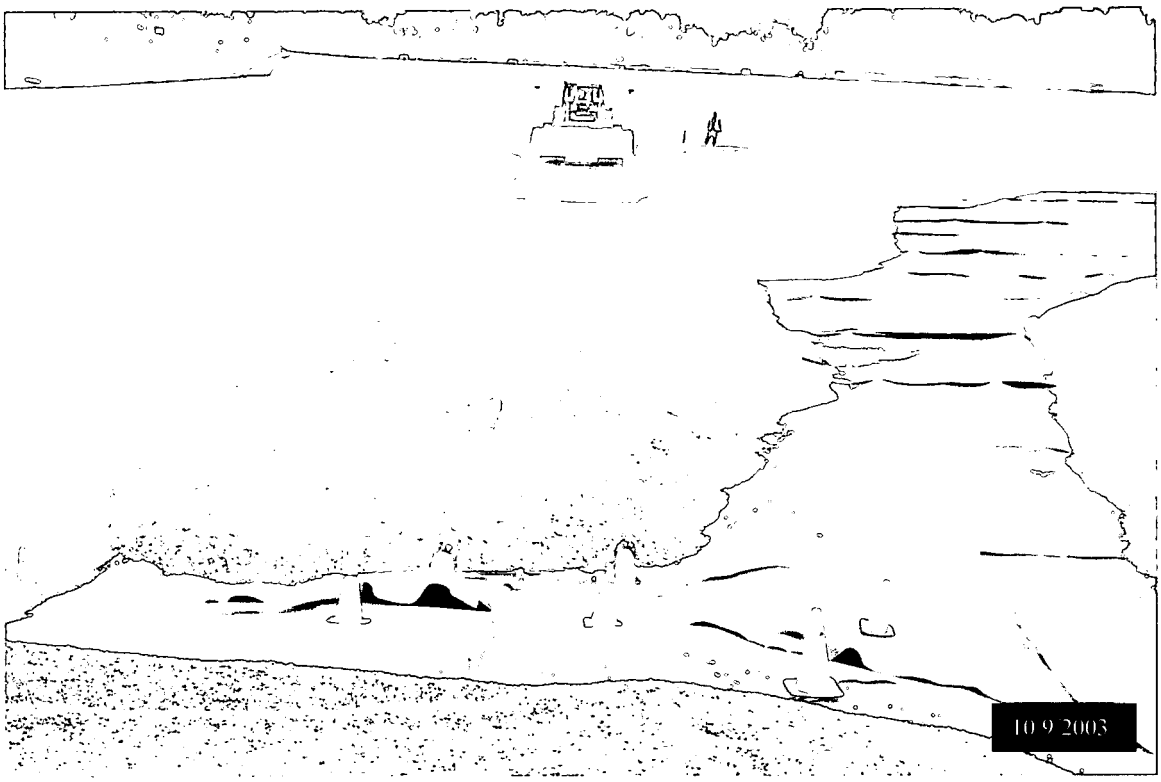

Photo # 52. Drainage stone placement over the primary GML.

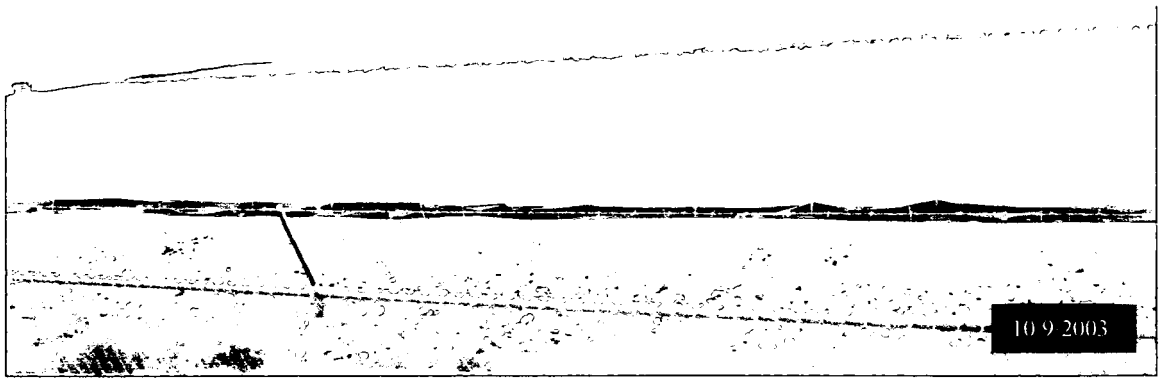

Photo # 53. Erosion mat deployment over topsoil on the Cell 2 Cap.

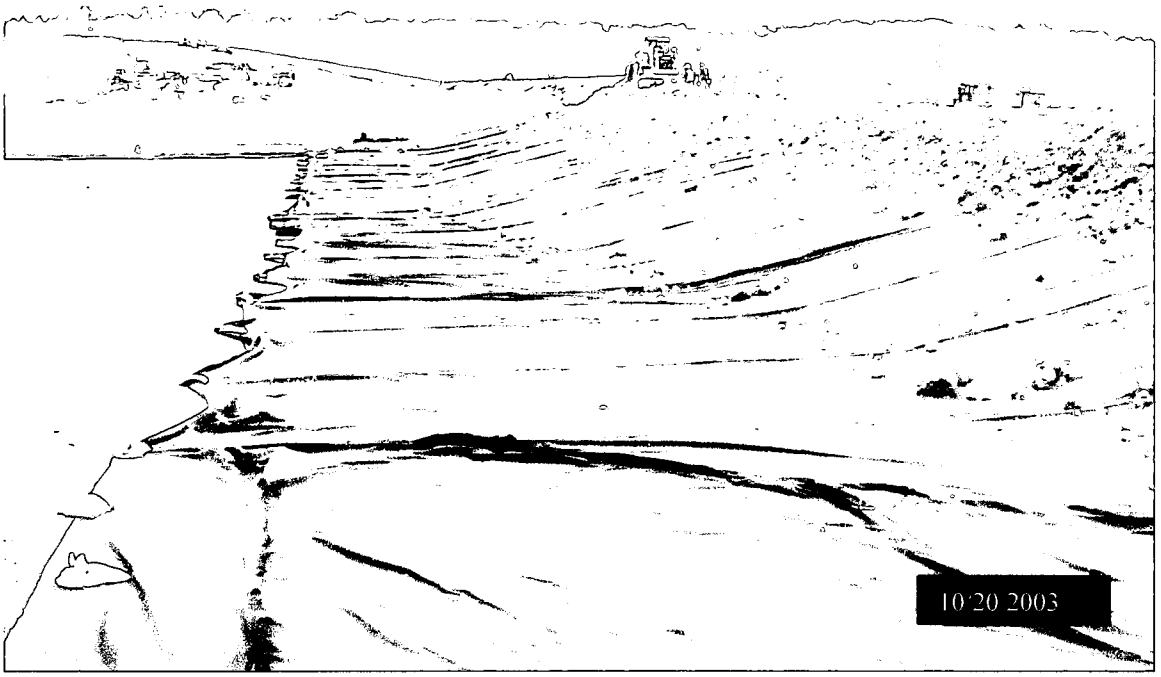

Photo # 54. Construction of the east clay wedge, Cell 6.

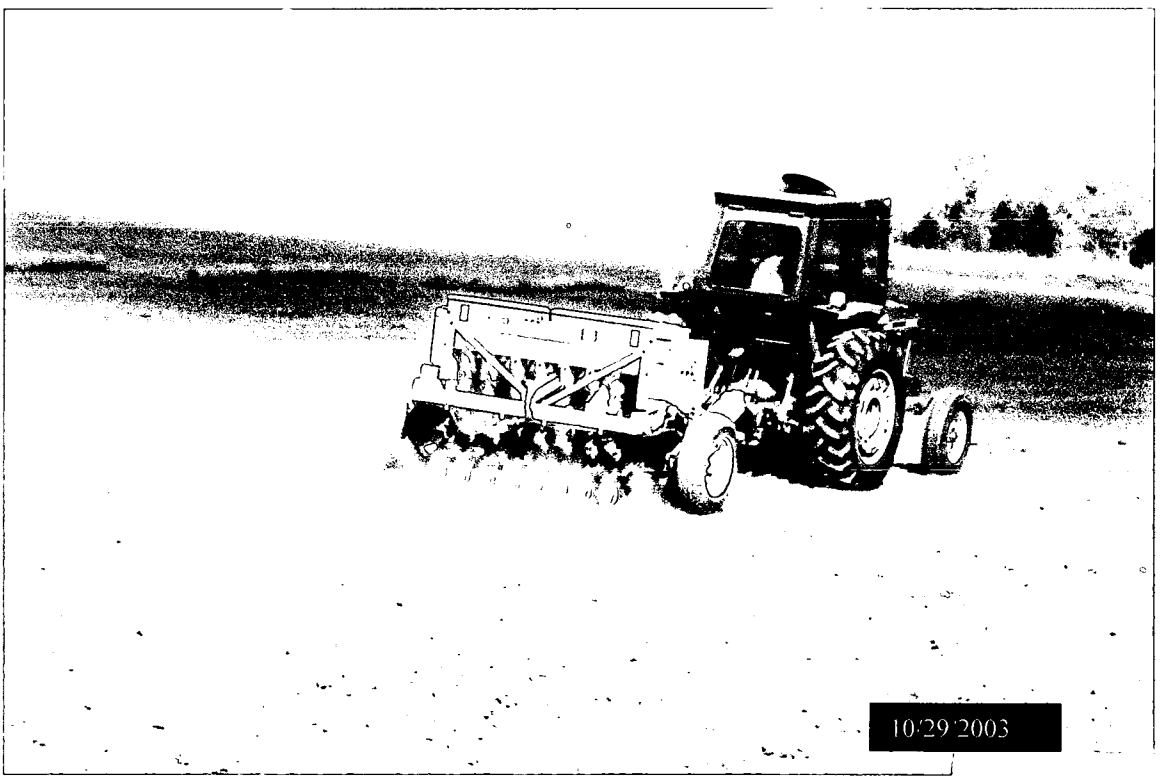

Photo # 55. Seeding of the Cell 2 Cap prior to placement of erosion matting.

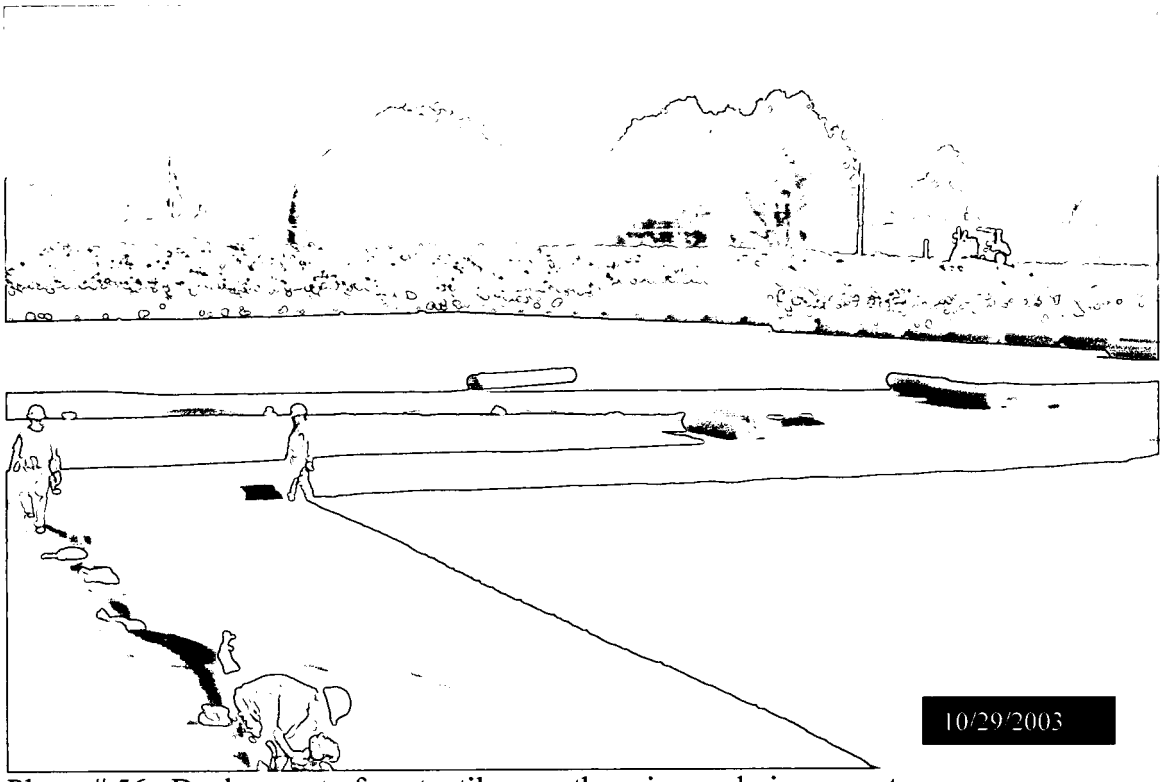

Photo # 56. Deployment of geotextile over the primary drainage system.