Addendum E

Final Remedial Action Plan
DOE-EM/GJ1547
June 2011

Remedial Action Inspection Plan (RAIP)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document</td>
<td>Remedial Action Inspection Plan (RAIP)</td>
</tr>
<tr>
<td>Attachment 1</td>
<td>Computer Aided Earthmoving System (CAES) For Landfills</td>
</tr>
</tbody>
</table>
Addendum E. Remedial Action Inspection Plan

Revision 3

June 2011
Statement of Policy

This Remedial Action Inspection Plan identifies the means by which the remedial action activities associated with the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project disposal cell at Crescent Junction, Utah, are controlled, verified, and documented. This plan has been developed within the scope of the Moab UMTRA Project Quality Assurance Plan for the Remedial Action Contractor (RAC) (DOE-EM/GJ1766), and complies with the applicable parts of American Society of Mechanical Engineers Nuclear Quality Assurance-1-2004, and addenda through 2007, “Quality Assurance Program for Nuclear Facilities,” Title 10 Code of Federal Regulations Part 830 Subpart A (10 CFR 830A), “Quality Assurance,” and DOE Order 414.1C, “Quality Assurance.”

The testing and inspection activities discussed in this plan are performed in accordance with the following applicable sections of the Quality Assurance Plan: Section 1.0, Organization; Section 2.0, Quality Assurance Program; Section 12.0, Control of Measuring and Testing Equipment; Section 15.0, Nonconforming Materials, Parts or Components; Section 16.0, Corrective Action; and Section 17.0, Quality Assurance Records.

Testing and Inspection

1.0 Purpose

The purpose of this plan is to describe the methods by which the construction activities will be tested and inspected to verify compliance with the Design Specification requirements.

2.0 Scope

This plan defines the testing and inspection of remedial action construction activities at the Crescent Junction site. Types of tests, test frequencies and acceptability, and documentation and reporting requirements are contained in this plan. Procedures for performing the individual tests shall be in accordance with the applicable ASTM International (ASTM) standards, the referenced or other approved methods, and the design specifications.

3.0 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials International</td>
</tr>
<tr>
<td>CAES</td>
<td>Computerized Aided Earthmoving System</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>D50</td>
<td>median stone diameter</td>
</tr>
<tr>
<td>DOE</td>
<td>U.S. Department of Energy</td>
</tr>
<tr>
<td>GPS</td>
<td>global positioning system</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>RAC</td>
<td>Remedial Action Contractor</td>
</tr>
<tr>
<td>RRM</td>
<td>residual radioactive material</td>
</tr>
<tr>
<td>UMTRA</td>
<td>Uranium Mill Tailings Remedial Action</td>
</tr>
</tbody>
</table>
4.0 Attachment

Attachment 1. Computerized Aided Earthmoving System Brochure

5.0 References


American Society of Mechanical Engineers (ASME), Nuclear Quality Assurance (NQA)-1 2004 and addenda through 2007 consensus standard, “Quality Assurance Requirements for Nuclear Facility Applications (QA).”

ASTM C88 – Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.


ASTM D1556 – Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.


ASTM D2922 – Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)


ASTM D4944 – Standard Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester.

ASTM D6938 – Standard Test Method for In-Place Density and Water content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).


6.0 General Requirements

6.1 General Approach to Soil Compaction And Compaction Testing

Typically, soil is tested in a laboratory to determine the maximum density that the particular soil can achieve. The maximum density will be achieved at the optimum moisture content for that soil. The laboratory maximum density and optimum moisture content for the soil becomes the basis of comparison for the compaction of the soil in the field.

In the field, the soil is placed in layers, compacted with specialized compaction equipment, and tested to confirm that the soil density is close to the previously determined laboratory maximum density. A variety of field tests have been used to determine soil density, including sand cone, rubber balloon, drive cylinder, and nuclear gauge methods. Moisture content tests are also needed to determine the in-place soil density. All of these test methods determine the density of a small quantity of soil at a single point in a large quantity of placed and compacted soil. A number of tests are required to infer that an entire layer of soil is adequately compacted. The documentation of soil compaction has typically consisted of a visual inspection report combined with a map of the compacted layer and the field test results.

6.1.1 Computer Aided Earthmoving System

Global positioning system (GPS) and computer terrain modeling technology have been combined to provide a new method of performing soil compaction. The equipment is called Computer Aided Earthmoving System (CAES). The system works as follows:

- A digital terrain model of the site to receive fill material is fed into an on-site computer linked to a computer in the cab of the compaction equipment. A GPS receiver is also linked to the compaction machine’s on-board computer. When the machine moves across the site, the GPS equipment provides the exact position and elevation of the equipment at all times.
- Soil is dumped and spread into a layer of fill. As the compaction machine spreads and compacts the layer of soil, the position of the machine is compared to the original terrain model to determine the location and thickness of the fill layer being installed. The on-board computer assists the equipment operator to place the material in a layer with uniform thickness by informing the operator of thick or thin areas of the fill.
• After a layer has been placed with uniform thickness, the compaction equipment makes multiple passes over the fill to compact the fill. A compaction machine, compacting material at the correct moisture content, will eventually compact the fill to near its maximum density such that additional compaction passes produce negligible change. The computer recording the GPS location data interprets the passes that produce no vertical change to indicate that the soil is at its maximum density.

• A record of each soil layer’s location, thickness, and compaction is generated by the computer.

Visual inspection, correct placement and compaction techniques, and good moisture control are still required to ensure that fill is properly placed, but the CAES method has distinct advantages over traditional field density testing. Lift thicknesses are computer controlled and are more uniform than when layers are installed based on visual estimates by the equipment operators. The computer checks compaction over the entire surface of every layer, whereas the in-place test methods only check a few points on each layer. See Attachment 1 for vendor data on the CAES.

Soil density verification tests and independent land surveys will be performed to demonstrate the effectiveness of the CAES. In the following sections of this plan, the verification testing and surveying will be described in detail for each element of the cell in which fill is placed.

6.2 Cell Excavation

Part of the proposed disposal cell will be below the ground surface in an excavation. The excavation will be constructed in phases with interim dikes that will be removed as operations require or as subsequent phases are constructed. The overall cell floor and side slopes are described below.

6.2.1 Floor and Side Slopes
The cell floor slopes 2.3 percent from northeast to southwest. The cut slopes on the north, west, and south sides of the cell slope at 2:1 or 3:1.

6.2.2 Final Floor and Embankment Elevations
The cell floor coordinates and elevations are shown on the design plans. When each section of the cell is excavated to the elevations indicated on the plans, a verification survey shall be performed to confirm that the excavation is to the proposed lines and grades. The verification survey shall be signed by the Contractor and submitted to the RAC Construction Manager.

6.2.3 Cell Floor in Weathered Mancos Shale
The cell floor elevation has been set based on test pit and soil boring data and is at least 2 feet below the top of the Mancos Shale at each data point. The cell floor shall be visually inspected to confirm that it is in the Mancos Shale formation. If an area is observed where the overburden soil extends below the cell floor, the area will be undercut, backfilled with prepared Mancos Shale, and compacted.
6.2.4 Inspection and Testing
Quality Control (QC) shall visually inspect the material and ground preparation. QC shall verify that the cell floor is constructed in accordance with plans and specifications by checking and confirming:
- Floor and side slopes are per the design plans.
- Final floor and side slopes survey match the coordinates and elevations in the plans.
- The floor is weathered Mancos Shale, or low spots have been compacted with Mancos Shale.

6.3 Embankment Construction
Part of the proposed disposal cell will be below the existing ground surface in an excavation, and part will be above the existing ground surface within a constructed embankment. The proposed embankment will have 3:1 or 2:1 interior slopes, 5:1 exterior slopes, and a minimum 30-foot-wide level top. Excavated material from the cell excavation will be used to construct the cell perimeter embankment.

6.3.1 Material
Excavated material from the cell excavation shall be segregated into four types of soil: topsoil, weathered Mancos Shale, common fill, and unsuitable material. Materials shall be stockpiled separately. The perimeter and spoils embankments will be constructed of common fill. The fill shall be tested to determine its maximum dry density in accordance with ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, and the moisture content shall be modified to bring the fill to its optimum moisture for compaction.

6.3.2 Ground Preparation
The ground beneath the proposed perimeter and spoils embankments shall be prepared by stripping vegetation and loose soil from the site, scarifying and compacting the top 6 inches of soil.

6.3.3 Lift Placement and Thickness
The embankment shall be constructed of fill materials placed in continuous and approximately horizontal lifts. The method of dumping and spreading fill shall result in loose lifts of nearly uniform thickness, not to exceed 12 inches.

At the RAC’s option, the compactor may be equipped with CAES and soil placement, and compaction shall be controlled by the CAES. The contractor may use CAES to determine and document compaction, or perform soil density tests in accordance with the Inspection and Testing, section below.

6.3.4 Inspection and Testing of Cell Perimeter Embankment
QC shall visually inspect the material preparation, ground preparation, and fill placement operations. QC shall perform in-place density tests with companion moisture tests to verify at least 95 percent of the laboratory maximum dry density in accordance with ASTM D698.

QC shall verify that the perimeter embankment is constructed in accordance with plans and specifications by checking and confirming:
- Interior slopes are 3:1, and exterior slopes are 5:1 with a minimum 30-foot-wide level top verified one time at the end of excavation.
- Fill material is properly moisture conditioned near optimum moisture.
• Fill material is placed in continuous and approximately horizontal lifts. The method of dumping and spreading material shall result in loose lifts of nearly uniform thickness, not to exceed 12 inches.
• Embankment construction soil is common fill.
• Compaction is properly performed.
• Compaction – Embankment fill shall be compacted with a minimum 45,000 pounds static weight compactor. The compactor shall be a footed roller capable of kneading compaction, with feet a minimum of 6 inches in length.
• Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the In-Place Density Testing sections below.
• Verification tests of in-place density shall be performed on initial layers of soil placed and on any specific type of material in which the CAES is used.

Testing and verification frequencies for lifts constructed without the CAES system shall be in accordance with the following:

**Testing of Cell Perimeter Embankment**

• For material compacted by other than hand-operated machines: One test per 50,000 square feet or 1,850 cubic yards of material placed, or fraction thereof, a minimum of one test for each lift of fill or backfill, and a minimum of two tests per day that fill is compacted in accordance with ASTM D6938.
• One test per 500 square feet, or fraction thereof, of each lift of fill or backfill areas for material compacted by hand-operated machines.

In place density and moisture content tests shall be performed in accordance with the following methods:

• ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
• ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
• ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
• ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
• Check Tests on In-Place Densities

If ASTM D6938 is used, check in-place densities by ASTM D1556 as follows:

• One check test for each 20 tests per ASTM D6938, of fill or backfill compacted by other than hand-operated machines.
• One check test for each 20 tests per ASTM D6938, of fill or backfill compacted by hand-operated machines.

**Optimum Moisture and Laboratory Maximum Density**

Perform laboratory density and moisture content tests (ASTM D698 and ASTM D2216) for each type of fill material to determine the optimum moisture (optimum moisture content plus or minus 5 percent) and laboratory maximum density values. One representative density test per material type and every 20,000 cubic yards thereafter or when any change in material occurs that may affect the optimum moisture content or laboratory maximum dry density.
One correlation test for moistures every 10 tests per ASTM 6938 will be performed in accordance with ASTM D4643 or D2216. In the stockpile, excavations, or borrow areas, perform moisture tests to control the moisture content of material being placed as fill.

Control of moisture content of fill shall be performed by conducting routine testing of moisture content by one of the following tests:
- ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
- ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
- ASTM D4944 – Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
- ASTM D4959 – Determination of Water (Moisture) Content of Soil by Direct Heating

During unstable weather, perform tests as dictated by local conditions and approved by the Construction Manager.

6.3.5 Disposal Cell Spoils Embankment (Wedge)
The spoils embankment is a fill embankment to be constructed north of the cell. The embankment will divert storm water from the Book Cliffs around the cell, and shall be constructed of surplus excavated material (spoils material) from the cell excavation. Prior to placement, spoils material shall be tested to determine its maximum dry density in accordance with ASTM D698, and the moisture content shall be modified to bring the fill to near optimum for compaction.

Constructing the Spoils Embankment
1. Prepare the ground beneath the proposed perimeter embankment by stripping vegetation and loose soil from the site.
2. Dump and spread fill in loose lifts of nearly uniform thickness, not to exceed 12 inches. Compact material with rollers, equipment tracks, or successive passes of scrapers. Fill shall be compacted to a density of 90 percent of the laboratory-determined maximum density in accordance with ASTM D698.

QC shall verify that the spoils embankment is constructed in accordance with plans and specifications by checking and confirming:
- Exterior slopes are 3:1.
- Fill material is properly moisture conditioned near optimum moisture.
- Fill material is placed in continuous and approximately horizontal lifts.
- The method of dumping and spreading material shall result in loose lifts of nearly uniform thickness, not exceed 12 inches.
- Embankment construction soil is common fill.
- Compaction is properly performed.
- Compaction – Embankment fill shall be compacted with rollers, equipment tracks, or successive passes of scrapers at a minimum 45,000 pounds static weight.
- Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the In-Place Density Testing sections below.
- Verification tests of in-place density shall be performed on initial layers of soil placed, and on any specific type of material in which the CAES is used.
Testing and verification frequencies for lifts constructed without the CAES system shall be in accordance with the following.

Testing of Spoils Embankment
- One test per 100,000 square feet or 3,700 cubic yards of material placed for material compacted by other than hand-operated machines
- One test per 500 square feet, or fraction thereof, of each lift of fill or backfill areas for material compacted by hand-operated machines

In place density and moisture content tests shall be performed in accordance with the following methods.
- ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
- ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
- ASTM D643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

Check Tests on In-Place Densities
If ASTM D6938 is used, check in-place densities with ASTM D1556 as follows.
- One check test for each 20 tests per ASTM D6938 of fill or backfill compacted by other than hand-operated machines.
- One check test for each 20 tests per ASTM D6938 of fill or backfill compacted by hand-operated machines.

Optimum Moisture and Laboratory Maximum Density
Perform laboratory density and moisture content tests (ASTM D698 and D2216) for each type of fill material to determine the optimum moisture (optimum moisture content plus or minus 5 percent) and laboratory maximum density values.

One representative density test per material type and every 20,000 cubic yards thereafter or when any change in material occurs which may affect the optimum moisture content or laboratory maximum dry density. One correlation test for moistures every 10 tests per ASTM D6938 will be performed in accordance with ASTM D4643 or D2216.

In the stockpile, excavations, or borrow areas, perform moisture tests to control the moisture content of material being placed as fill. Control of moisture content of fill shall be performed by conducting routine testing of moisture content by one of the following tests.
- ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
- ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
- ASTM D4944 – Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
- ASTM D959 – Determination of Water (Moisture) Content of Soil by Direct Heating
During unstable weather, perform tests as dictated by local conditions and approved by the Construction Manager.

### 6.4 Residual Radioactive Material

The objective is to place and compact the residual radioactive material (RRM) in the waste cell to create a stable waste mass. QC shall visually inspect the material preparation, ground preparation, and RRM placement operations, and shall perform in-place density tests with companion moisture tests for the CAES to verify that RRM compaction meets the compaction requirements. QC shall verify that the RRM placement is performed in accordance with plans and specifications, and that the top of the placed waste matches the final grades identified in Section 6.4.5. RRM shall not be placed when frozen or over frozen subgrade. If rainwater ponding has occurred, placement of RRM shall only be performed after the area is dewatered, and approval of the Construction Manager and QC to place is obtained.

#### 6.4.1 Moisture Modification

RRM material should be shipped from the Moab site at or near optimum moisture for compaction. Some RRM may require minor moisture modification when received at Crescent Junction site.

#### 6.4.2 RRM Placement

Scarify at a minimum the top 1 inch of subsoil or preceding RRM lift using a footed roller or a dozer prior to placement of subsequent RRM layers. Fill materials shall be placed in continuous and planar lifts. The method of dumping and spreading RRM shall result in loose lifts of nearly uniform thickness, average thickness not to exceed 12 inches. Compaction equipment shall consist of footed rollers or dozers. Footed rollers shall have a minimum weight of 45,000 pounds and at least one tamping foot shall be provided for each 110 square inches of drum surface. The length of each tamping foot from the outside surface of the drum shall be at least 6 inches. During compaction operations, the spaces between the tamping feet shall be maintained clear of materials that would impair the effectiveness of the tamping foot rollers. Dozers shall have a minimum ground pressure of 1,650 pounds per feet. The CAES may be used to direct fill placement, monitor compaction, and record the location and thickness of each soil layer being placed.

#### 6.4.3 Inspection and Testing

QC shall visually inspect the ground preparation and fill placement operations. RRM shall be compacted to meet 90 percent of the laboratory determined maximum dry density as determined by ASTM D698. QC shall verify that the RRM placement is constructed in accordance with design plans and specifications by checking and confirming:

- Assessment tests shall be performed on RRM to ensure compliance with specified requirements and to develop compaction requirements for placement. A minimum of three tests for maximum dry density (ASTM D698) and optimum moisture content (optimum moisture plus or minus 3 percent) (ASTM D2216) shall be performed for each type of RRM soil observed.
- Fill material is properly moisture conditioned; one moisture content quick test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959 until a sufficient number have been performed to demonstrate a clear correlation allowing a reduction in testing.
• Fill material is placed in continuous and planar lifts. The method of dumping and spreading RRM shall result in loose lifts of nearly uniform thickness, average thickness of fill area not to exceed 12 inches.
• Compaction meets specifications.
• Compaction by CAES – QC shall monitor CAES compaction by visually inspecting the process and reviewing the computer records for each layer of soil placed.
• Verification tests of in-place density shall be performed on the initial layer of RRM and on any layers in which the CAES indicates that problems occurred obtaining compaction. In-place density will be taken every 6 months to verify the performance of the CAES.

NOTE: Companion sand cone and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If CAES is not used, the following testing requirements shall be followed.
• Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the following requirements.
  o A verification representative sample from each principal type or combination of blended RRM materials shall be tested to establish compaction curves using ASTM D698.
  o A minimum of one set of compaction curves shall be developed per 10,000 cubic yards of RRM material.
  o In-place density and moisture content tests are performed on a soil layer; a minimum of two tests shall be performed per 5,000 cubic yards or 135,000 square feet of fill material placed.
• Compaction and moisture content tests shall be performed in accordance with the following methods.
  o ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
  o ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
  o ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
  o ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
• After lift placement, moisture content shall be maintained until the next lift is placed.
• Erosion that occurs in the RRM layers shall be repaired and grades re-established.
• Freezing and desiccation of the RRM soil shall be prevented. If freezing or desiccation occurs, the affected soil shall be reconditioned as directed.
• Areas that have been repaired shall be retested as directed. Repairs to the RRM layers shall be documented including location and volume of soil affected, corrective action taken, and results of retests.

6.4.4 Demolition Debris
Demolition debris will be placed in the waste cell along with RRM. Each container of demolition debris shall be spread in a single layer, not stacked, and placed in a manner that results in a minimum of voids around the debris. The following materials will be placed in the waste cell:
• Wood, Concrete, Masonry: Cut or break up to a maximum 3-foot size measured in any dimension.
• Structural Steel Member, Pipes, Ducts, other Long Items: Cut into maximum 10-foot lengths.
- Concrete, Clay Tile, and other Pipes: Crush concrete and clay tile pipes. Crush other pipes and ducts that are 6 inches or greater in diameter or, if crushing is impractical, cut pipes and ducts in half longitudinally. Do not crush asbestos-cement pipe.
- Rubber Tires Excavated at the Site: Cut into two halves around the circumference.
- Geomembranes and other Sheet Material: Cut into strips a maximum of 4 feet wide by 4 feet long.
- Tree Limbs 4 inches in Diameter and Larger: Cut into lengths of 8 feet or less.

6.4.5 Final RRM Geometry
The top surface of the RRM shall be no greater than 2 inches above the lines and grades shown on the drawings and verified by survey or the use of the CAES. No minus tolerance will be permitted.

6.5 Interim Cover

After a section the RRM has been placed in the waste cell to final grade and verified by survey, an interim cover consisting of 1 foot of clean, compacted soil shall be placed over the RRM. Interim cover material will be placed and compacted directly on top of RRM to provide a buffer of uncontaminated soil prior to the placement of the final multi-layer cap.

6.5.1 Material
Interim cover soil will be soil from the excavation of the Crescent Junction waste cell. It will be material that has been produced on site by modifying the existing overburden soil and weathered Mancos Shale excavated on site. Overburden and weathered Mancos Shale shall be excavated, pulverized, wetted, and mixed to produce a uniform fine-grained soil near optimum moisture content for compaction. Soil shall be free of roots, debris, and organic or frozen material.

6.5.2 Ground Preparation
The RRM beneath the proposed interim cover shall be prepared by scarifying to a minimum depth of one inch prior to the placement of the initial lift of interim cover soil.

6.5.3 Lift Placement and Thickness
The interim cover shall be constructed of fill materials placed in continuous lifts of uniform thickness. The method of dumping and spreading interim cover soil over the RRM shall result in loose lifts with average thickness not to exceed 12 inches.

6.5.4 Inspection and Testing
The QC shall visually inspect the ground preparation and fill placement operations. The interim cover layer shall be compacted to meet 90 percent of the laboratory determined maximum dry density as determined by ASTM D698. QC shall verify that the interim cover is constructed in accordance with plans and specifications by checking and confirming:
- A representative sample from each type or combination of stockpiled excavated soil for use as interim cover soil shall be tested to establish a compaction curve using ASTM D698.
- Interim cover is properly moisture conditioned, one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959, moisture content shall be plus or minus 5 percent.
- Interim cover is placed in continuous and approximately horizontal lifts. The method of dumping and spreading interim cover shall result in loose lifts of nearly uniform thickness, with average thickness not to exceed 12 inches.
• Compaction is properly performed.
• Compaction by CAES – QC shall monitor CAES compaction by visually inspecting the process and reviewing the computer records for each layer of soil placed.
• Verification tests of in-place density shall be performed on the first 5,000 cubic yards of interim cover and on any layers in which the CAES indicates that problems occurred obtaining compaction.

NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If CAES is not used, the following testing requirements shall be followed.
• Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the following requirements.
  o When verification, in-place density, and moisture content tests are performed on a soil layer, a minimum of two tests shall be performed per 5,000 cubic yards or 135,000 square feet of fill material placed.
  o A representative sample from each type or combination of stockpiled excavated soil for use as interim cover soil shall be tested to establish a compaction curve using ASTM D698.
  o Interim cover is properly moisture conditioned; one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959, moisture content shall be plus or minus 5 percent.
  o Interim cover is placed in continuous and approximately horizontal lifts. The method of dumping and spreading interim cover shall result in loose lifts of nearly uniform thickness, with average thickness not to exceed 12 inches.
  o Compaction is properly performed.
  o Compaction and moisture content tests shall be performed in accordance with the following methods:
    - ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
    - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
    - ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
    - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
    - ASTM D698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort

NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

• After lift placement, moisture content shall be maintained until the next lift is placed.
• Erosion that occurs in the interim cover layer shall be repaired and grades re-established.
• Freezing and desiccation of the interim cover soil shall be prevented. If freezing or desiccation occurs, the affected soil shall be reconditioned as directed.
• Areas that have been repaired shall be re-tested as directed. Repairs to the interim cover layer shall be documented, including location and volume of soil affected, corrective action taken, and results of retests.
6.5.5 Final Interim Cover Geometry
Proof roll the interim cover with rubber-tired construction equipment, such as a loaded dump truck or loaded scraper, with a minimum weight of 45,000 pounds to produce a smooth compacted surface on the top of the completed interim cover layer, such that direct rainfall causes minimal erosion. The top surface of the interim cover shall be no greater than 2 inches above the lines and grades shown on the drawings. No minus tolerance will be permitted.

6.6 Cap Construction

An UMTRA cover, a multi-layer cap, will be constructed over the RRM and interim cover. The cap materials and configuration are intended to protect the RRM from exposure due to water erosion, wind erosion, and burrowing animals for a design life of 1,000 years. The proposed cap layers are shown in the UMTRA cover design figure in Section 6.7.1.

6.7 Radon Barrier Layer

The initial cap layer is a 4-foot-thick radon barrier layer constructed of compacted clay soil. The radon barrier will be a low-permeability clay layer that limits radon emissions from the RRM and limits the infiltration of water from above.

6.7.1 Material
The radon barrier layer will be constructed of processed Mancos Shale. The clay soil will be produced on site by processing excavated Mancos Shale into a fine-grained soil and adding water to bring the Mancos Shale to near optimum moisture content for compaction.

Assessment tests shall be performed on radon barrier material to ensure compliance with specified requirements and to develop compaction requirements for placement. A minimum of three tests for maximum dry density (ASTM D698); optimum moisture content (ASTM D2216) shall be performed for each type of soil observed to establish the optimum moisture for radon barrier material placement. Mancos Shale soil produced for radon barrier fill shall be tested to determine its maximum dry density and the optimum moisture content. The moisture content shall be modified to bring the fill to optimum for compaction.

As a minimum, perform the following soil tests on each 10,000 cubic yards of soil:
- ASTM D4318, Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D1140, Amount of Material in Soils Finer than the No. 200 Sieve
- ASTM D422, Standard Test Method for Particle-Size Analysis in Soil
- ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
- ASTM D2216, Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass and/or ASTM D4643, Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

6.7.2 Ground Preparation
The interim cover layer beneath the proposed radon barrier layer shall be prepared by scarifying to a minimum depth of 1 inch prior to the placement of the initial lift of radon barrier soil.
6.7.3 Lift Placement and Thickness
The radon barrier layer shall be constructed of fill materials placed in continuous lifts of uniform thickness. The method of dumping and spreading radon barrier shall result in loose lifts not to exceed 12 inches. Compaction equipment shall consist of rubber tired or footed roller compaction equipment with a minimum weight of 45,000 pounds. The in-place material may contain particles up to 4 inches.

Placement of Mancos Shale will be visually inspected to make sure there are no locations where rock type particles accumulate in a concentrated location. Particles found in a concentrated location will be removed or reworked per QC direction.
6.7.4 Inspection and Testing

QC shall visually inspect the processing of Mancos Shale into clay soil, ground preparation, and fill placement operations. QC shall perform in-place density tests with companion moisture tests to verify optimum moisture plus or minus 3 percent and at least 95 percent of the material’s maximum dry density according to ASTM D698.

QC shall verify that the radon barrier is constructed in accordance with plans and specifications by checking and confirming:

- Fill material is properly moisture conditioned; one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959 with moisture content plus or minus 3 percent.
- Material is placed in continuous uniform thickness lifts. The method of dumping and spreading radon barrier shall result in loose lifts not to exceed 12 inches.
- Radon barrier soil is processed Mancos Shale.
- Tests have been performed on the processed shale soil to determine its maximum dry density and optimum moisture content.
- Compaction – Radon barrier fill is compacted with rubber tired or footed roller compaction equipment.
- Compaction by CAES – QC shall monitor CAES compaction by visually inspecting the process and reviewing the computer records for each layer of soil placed.
- Verification tests of in-place density shall be performed on initial layer of radon barrier placed, and on any layers in which the CAES indicates that problems occurred obtaining compaction.
- Maximum particle size in the fill material shall be 4 inches
- Placement of mancos shale will be visually inspected to make sure there are no locations where rock-type particles accumulate in a concentrated location

NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If CAES is not used, the following testing requirements shall be followed.

- Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the following requirements:
  - A verification representative sample from each principal type or combination of blended radon barrier materials shall be tested to establish compaction curves using ASTM D698. A minimum of one set of compaction curves shall be developed per 10,000 cubic yards of radon barrier material.
  - In-place density and moisture content tests are performed on a soil layer; a minimum of two tests shall be performed per 5,000 cubic yards or 135,000 square feet of fill material placed.
  - Fill material is properly moisture conditioned; one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959, with moisture content plus or minus 3 percent.
  - Material is placed in continuous uniform thickness lifts. The method of dumping and spreading radon barrier shall result in loose lifts not to exceed 12 inches.
  - Radon barrier soil is processed Mancos Shale.
  - Tests have been performed on the processed shale soil to determine its maximum dry density and optimum moisture content.
Compaction – Radon barrier fill is compacted with rubber tired or footed roller compaction equipment.

- Maximum particle size in the fill material shall be 4 inches.
- Placement of Mancos Shale will be visually inspected to make sure there are no locations where rock-type particles accumulate in a concentrated location.
- Compaction and moisture content tests shall be performed in accordance with the following methods.
  - ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
  - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
  - ASTM D6938 – In-Place Density and Water content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
  - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

**NOTE:** Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

- After placement, moisture content shall be maintained or adjusted to meet criteria.
- Erosion that occurs in the fill layers shall be repaired and grades re-established.
- Freezing and desiccation of the radon barrier layer shall be prevented. If freezing or desiccation occurs, the affected soil shall be removed or reconditioned as directed.
- Areas that have been repaired shall be retested as directed. Repairs to the radon barrier layer shall be documented, including location and volume of soil affected, corrective action taken, and results of retests.

**6.7.5 Initial and Confirmatory Surveys**

Verification of the thickness of the radon barrier layer will be performed by comparing before and after surveys of the layer by surveying or using CAES. Prior to placement of the radon barrier layer, an initial survey shall be performed of the section to be capped. The initial survey will document the pre-cap geometry of the site. After the radon barrier layer has been installed, a post-installation survey will be performed on the top of the radon barrier fill to confirm that the total fill thickness is in accordance with the plans and specifications.

**6.8 Infiltration and Biointrusion Barrier (Gravel)**

Above the radon barrier layer, a 6-inch-thick infiltration and biointrusion layer of gravel will be placed to provide a barrier to burrowing animals, and a pathway for drainage of water that has infiltrated through upper layers of the cap. The gravel will be a sandy gravel with a gradation in accordance with Project plans and specifications. Rock shall be spread to the thickness indicated on the drawings or in accordance with oversizing due to scoring criteria. Rock placement shall be guided by GPS grade control to ensure the appropriate thickness has been placed at all locations. The biointrustion layer shall be compacted with a vibratory steel drum.
6.8.1 Erosion Protection Materials Testing

Rock for the infiltration and biointrusion barrier layer shall be tested by a commercial testing laboratory during production in accordance with the following.

**Riprap Type A and B, and Bedding Material**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity (SSD)</td>
<td>ASTM C127 (Absorption)</td>
</tr>
<tr>
<td>Sodium Sulfate Soundness (5 cycles)</td>
<td>ASTM C88 (Coarse Aggregate)</td>
</tr>
<tr>
<td>L.A. Abrasion (100 cycles)</td>
<td>ASTM C131 (Abrasion)</td>
</tr>
</tbody>
</table>

**Riprap Type C and D**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schmidt Rebound Hardness</td>
<td>International Society for Rock Mechanics (ISRM) Method</td>
</tr>
<tr>
<td>Splitting Tensile Strength</td>
<td>ISRM Method</td>
</tr>
</tbody>
</table>

Test results shall be submitted to a commercial testing lab for analysis and subsequent acceptance or rejection or the material represented by the test results, based on engineering calculations.

Rock for the infiltration and biointrusion barrier layer shall be tested for gradation in accordance with ASTMs C-117 and C-136, and other approved testing methods. Test results shall be in accordance with the Design Specification.

Rock for the infiltration and biointrusion barrier layer shall be tested a minimum of four times. The materials shall be tested initially prior to the delivery of any of the materials to the site. Thereafter, the tests shall be performed in place at a minimum frequency of one test for each 5,000 cubic yards or fractions thereof produced/placed (durability tests for materials produced/gradation tests for materials placed). A final set of durability tests shall be performed near completion of production for each type material. A final gradation test shall be performed near completion of placement for each type material.

Rock for the infiltration and biointrusion barrier layer shall be material that has long-term chemical and physical durability. The material shall achieve an acceptable score for its intended use, in accordance with the rock scoring and acceptance criteria.

6.8.2 Rock Acceptance Criteria

An acceptable rock score depends on the intended use of the rock. The rock’s score must meet the following criteria.

- For occasionally saturated areas, which include the top and sides of the final cover, the rock must score at least 50 percent or the rock is rejected. If the rock scores between 50 percent and 80 percent, the rock may be used, but a larger median stone diameter (D50) must be provided (oversizing). If the rock score is 80 percent or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65 percent or the rock is rejected. If the rock scores between 65 percent and 80 percent, the rock may be used, but must be oversized. If the rock score is 80 percent or greater, no oversizing is required.
Oversizing Rock
- Subtract the rock score from 80 percent to determine the amount of oversizing required. For example, a rock with a rating of 70 percent will require oversizing of 10 percent (80 percent – 70 percent = 10 percent).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10 percent oversizing factor and a D50 of 12 inches will increase to a D50 of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D50 rock size. For example, a layer thickness equals twice the D50, such as when the plans call for 24 inches of stone with a D50 of 12 inches, if the stone D50 increases to 13.2, the thickness of the layer of stone with a D50 of 13.2 should be increased to 26.4 inches.

QC shall verify that the infiltration and biointrusion layer is installed in accordance with plans and specifications by checking and confirming:
- Gravel material gradation matches the gradation required in the specifications.
- Gravel material is placed and compacted to produce a continuous uniform thickness of at least 6 inches.
- Compaction is performed by a vibratory steel drum roller, and that the roller makes a minimum of two passes over the placed gravel fill.

6.9 Frost Protection Layer

Above the infiltration and biointrusion layer a 3-foot-thick frost protection layer will be installed. This soil layer will provide protection for the low-permeability radon barrier layer beneath. The frost protection layer will consist of 3 feet of clean, compacted soil that shall be placed directly on the gravel infiltration and biointrusion layer.

6.9.1 Material
The frost protection layer will be constructed of common fill. The fill shall come from the cell excavation, tested to determine its maximum dry density, and the moisture content modified to bring the fill to optimum for compaction in accordance with ASTM D698.

6.9.2 Ground Preparation
The frost protection layer will be placed directly on the gravel infiltration and biointrusion layer.

6.9.3 Lift Placement and Thickness
The frost protection layer shall be constructed of fill materials placed in continuous lifts of uniform thickness. The method of dumping and spreading of the frost protection layer shall result in loose lifts average thickness not to exceed 12 inches. Scarification shall be performed on all areas of the upper surface of each underlying soil layer prior to placement of the next lift. The final lift of soil shall not be scarified. The final lift shall be smooth rolled with at least three passes of the approved smooth steel wheeled roller weighing a minimum of 20,000 pounds.

6.9.4 Inspection and Testing
QC shall visually inspect the material preparation, ground preparation, and fill placement operations. QC shall perform in-place density tests with companion moisture tests optimum moisture plus or minus 5 percent and at least 90 percent of the material’s maximum dry density according to ASTM D698 on the initial layer.
QC shall verify that the frost protection layer is constructed in accordance with plans and specifications by checking and confirming:

- Frost protection layer soil is common fill.
- Tests have been performed on the common fill to determine its maximum dry density and optimum moisture content per ASTM D698.
- Fill material is properly moisture conditioned to near optimum moisture.
- Fill material is placed in continuous and approximately horizontal lifts. The method of dumping and spreading the frost protection layer shall result in loose lifts of nearly uniform thickness, average thickness not to exceed 12 inches.
- Compaction is properly performed.
- Compaction – Frost Protection fill will be compacted with rubber tired or footed roller compaction equipment.
- Compaction by CAES – QC shall monitor CAES compaction by visually inspecting the process and reviewing the computer records for each layer of soil placed.
- Verification tests of in-place density shall be performed on initial layers of soil placed, and on any layers in which the CAES indicates that problems occurred obtaining compaction.

**NOTE:** Companion sand cone and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If CAES is not used, the testing requirements below shall be followed.

- Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the following requirements:
  - When verification, in-place density, and moisture content tests are performed on a soil layer, a minimum of 2 tests per 5,000 cubic yards or 135,000 square feet of fill material placed.
  - Frost protection layer soil is common fill.
  - Tests have been performed on the common fill to determine its maximum dry density and optimum moisture content per ASTM D698.
  - Fill material is properly moisture conditioned to near optimum moisture.
  - Fill material is placed in continuous and approximately horizontal lifts. The method of dumping and spreading the frost protection layer shall result in loose lifts of nearly uniform thickness, with average thickness not to exceed 12 inches.
  - Compaction is properly performed.
  - Compaction – Frost protection fill will be compacted with rubber tired or footed roller compaction equipment.
  - Compaction and moisture content tests shall be performed in accordance with the following methods:
    - ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
    - ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
    - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
    - ASTM D2922 – Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
    - ASTM D6938 – In-Place Density and Water content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
    - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
NOTE:  Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

6.9.5 Initial and Confirmatory Surveys
Verification of the thickness of the frost protection layer will be performed by comparing before and after surveys of the layer. Prior to placement of the frost protection layer, an initial survey shall be performed of the section to be capped. The initial survey will document the geometry of the top of the infiltration and biointrusion layer. After the frost protection layer has been installed, a post-installation survey will be performed on the top of the frost protection layer to confirm that the total fill thickness is in accordance with the plans and specifications.

6.10 Rock Armoring
The final cap layer is rock armoring, placed over the frost protection layer. The rock armoring will vary in size and thickness at different locations on the cap, and shall be installed in accordance with the Project plans and specifications. Rock shall be spread to the thickness indicated on the drawings or in accordance with oversizing due to scoring criteria. Rock placement shall be guided by a GPS system to ensure the appropriate thickness has been placed at all locations. Stone shall be compacted with a vibratory steel drum.

6.10.1 Erosion Protection Materials Testing
Rock for the final cover layers shall be tested by a commercial testing laboratory during production in accordance with the following:

<table>
<thead>
<tr>
<th>Rock Armoring</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity (SSD)</td>
<td>ASTM C127 (Absorption)</td>
</tr>
<tr>
<td>Sodium Sulfate Soundness (5 cycles)</td>
<td>ASTM C88 (Coarse Aggregate)</td>
</tr>
<tr>
<td>L.A. Abrasion (100 cycles)</td>
<td>ASTM C131 (Abrasion)</td>
</tr>
<tr>
<td>Schmidt Rebound Hardness</td>
<td>ISRM Method</td>
</tr>
</tbody>
</table>

Test samples shall be submitted to a commercial testing lab for analysis and subsequent acceptance or rejection of the material represented by the test results, based on engineering calculations.

Rock for the final cover layers shall be tested for gradation in accordance with ASTMs C-117 and C-136, and other approved testing methods. Test results shall be in accordance with the Design Specification.

Rock for the final cover layers shall be tested a minimum of four times. The materials shall be tested initially prior to the delivery of any of the materials to the site and at the beginning of placement. Thereafter, the tests shall be performed in place at a minimum frequency of one test for each 5,000 cubic yards or fractions thereof produced/placed (durability tests for materials produced/gradation tests for materials placed).

A final set of durability tests shall be performed near completion of production for each type material. A final gradation test shall be performed near completion of placement for each type material.
Rock for the final cover layers shall be rock material that has long-term chemical and physical durability. Rock for final cover layers shall achieve an acceptable score for its intended use, in accordance with the rock scoring and acceptance criteria.

Periodically, a geologist will inspect the stockpiles at the quarry operations periodically to ensure the percentage of other than grey basalt does not exceed 10 percent for rock for the final cover layers.

6.10.2 Rock Acceptance Criteria

An acceptable rock score depends on the intended use of the rock. The rock’s score must meet the following criteria:

- For occasionally saturated areas, which include the top and sides of the final cover, the rock must score at least 50 percent, or the rock is rejected. If the rock scores between 50 percent and 80 percent, the rock may be used, but a larger D50 must be provided (oversizing). If the rock score is 80 percent or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65 percent, or the rock is rejected. If the rock scores between 65 percent and 80 percent, the rock may be used, but must be oversized. If the rock score is 80 percent or greater, no oversizing is required.

Oversizing Rock

- Subtract the rock score from 80 percent to determine the amount of oversizing required. For example, a rock with a rating of 70 percent will require oversizing of 10 percent (80 percent – 70 percent = 10 percent).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10 percent oversizing factor and a D50 of 12 inches will increase to a D50 of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D50 rock size. For example, a layer thickness equals twice the D50, such as when the plans call for 24 inches of stone with a D50 of 12 inches; if the stone D50 increases to 13.2, the thickness of the layer of stone with a D50 of 13.2 should be increased to 26.4 inches.

QC shall verify that the rock armoring is installed in accordance with plans and specifications by checking and confirming:

- Stone material is placed to produce the thickness required by the plans for each area. As a minimum, depth verification will be performed every 10,000 cubic yards.

6.11 Settlement Monitoring

A grid system shall be established for periodic surveys to monitor cell settlement. This system will be transferred to DOE Legacy Management for continued cell settlement monitoring.
Cell Construction Material Installation Summary Table

<table>
<thead>
<tr>
<th>Cell Component</th>
<th>Material of Construction</th>
<th>Compaction Requirements</th>
<th>Lift Thickness max/approx loose/compact</th>
<th>Frequency of Verification Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Excavation</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Perimeter Embankment</td>
<td>Common Fill</td>
<td>95 percent</td>
<td>12 inches/10 inches</td>
<td>Initial layer/Section 6.3.4</td>
</tr>
<tr>
<td>RRM Placement</td>
<td>RRM</td>
<td>90 percent</td>
<td>Average thickness 12 inches/10 inches</td>
<td>Initial layer/Section 6.4.3</td>
</tr>
<tr>
<td>Interim Cover</td>
<td>Common Fill</td>
<td>90 percent</td>
<td>Average 12 inches/10 inches</td>
<td>Initial layer/Section 6.5.4</td>
</tr>
<tr>
<td>Radon Barrier</td>
<td>Weathered Mancos Shale</td>
<td>95 percent</td>
<td>12 inches/10 inches</td>
<td>Initial layer/Section 6.7.4</td>
</tr>
<tr>
<td>Infiltration and Biointrusion Barrier</td>
<td>Stone</td>
<td>NA</td>
<td>Average thickness 12 inches/10 inches</td>
<td>Initial layer/Section 6.9.4</td>
</tr>
<tr>
<td>Frost Protection</td>
<td>Common Fill</td>
<td>90 percent</td>
<td>Average thickness 12 inches/10 inches</td>
<td>Initial layer/Section 6.9.4</td>
</tr>
<tr>
<td>Cap Armoring</td>
<td>Stone</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

approx = approximate; max = maximum; NA = not applicable

7.0 Records

Test and inspection records shall be reported and filed in a timely manner, consistent with the status of work performed. Inspection and test status shall be available at all times to prevent inadvertent by-passing of an inspection or test.

Test and inspection records shall contain the following, at a minimum.

- Items tested or inspected
- Date of test or inspection
- Tester/inspector
- Type of test or inspection
- Results and acceptability, including the test or inspection acceptance criteria
- Identification number of instrument used in performing the test or inspection
- Action taken in connection with any deviations noted
- Person evaluating test results, if different from person named in paragraph

Test and inspection records shall be filed and maintained in accordance with the Moab UMTRA Project Records Management Manual (DOE-EM/GJT1545). Surveillances shall be performed by Quality Assurance of measuring and test equipment used by QC. Daily Inspection Reports shall be generated, describing the adequacy, discrepancies, progress, dispositions and details of each day’s construction activities. Permanent Quality Assurance/QC records shall be periodically evaluated through internal and external surveillances and audits.

A weekly QC Report shall be generated, summarizing the volume of in-placed materials and the number of field and laboratory tests performed for each type of material. A copy of the weekly QC Report shall be transmitted to the RAC Quality Manager.
ADDENDUM E

Attachment 1

Computer Aided Earthmoving System
Landfill Compactors
Track-Type Tractors
Wheel Tractor Scrapers
Motor Graders

System Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications Radio</td>
<td>TC900B</td>
</tr>
<tr>
<td>GPS Antenna</td>
<td>L1/L2</td>
</tr>
<tr>
<td>GPS Receiver</td>
<td>MS840</td>
</tr>
<tr>
<td>In-Cab Display</td>
<td>CAES Touch Screen Display</td>
</tr>
<tr>
<td>CAESoffice™/METSmanager</td>
<td></td>
</tr>
</tbody>
</table>
Computer Aided Earthmoving System for Landfills

Advanced GPS technologies for earthmoving equipment improve machine efficiency, maximize air space utilization, and extend landfill life.

Caterpillar is helping customers revolutionize the way they compact trash, grade slopes and manage their operation with new technology solutions for landfills. Solutions that provide greater accuracy, higher productivity, lower operating costs, more profitability and longer landfill life.

The Computer Aided Earthmoving System (CAES) is a high technology earthmoving tool that allows machine operators to achieve maximum landfill compaction, desired grade/slope, and conserve and ensure even distribution of valuable cover soil with increased accuracy without the use of traditional survey stakes and crews. Using global positioning system (GPS) technology, machine-mounted components, a radio network, and office management software, this state-of-the-art machine control system delivers real-time elevation, compaction and grade control information to machine operators on an in-cab display. By monitoring grade and compaction progress, operators have the information they need to maximize the efficiency of the machine, resulting in proper drainage and optimum airspace utilization.

This advanced technology tool also aids in the identification of site-specific storage areas for hazardous, medical, industrial, and organic waste requiring special handling and placement records.

Applications
CAES is an ideal tool for landfill planning, engineering, surveying, grade control, and production monitoring applications in dump areas. CAES is specifically designed for use on landfill compactors, track-type tractors, wheel tractor scrapers, and motor graders.

On-Board Components
- CAES Touch Screen Display
- GPS Receiver
- GPS Antenna (L1/L2)
- Communications Radio

Off-Board Components
- GPS Reference Station
- Radio Network
- CAESoffice/METSTracker

Operation
CAES uses GPS technology, a wireless radio communications network, and office software to map landfills, create site plans, locate a machine’s position, and track compaction and earthmoving progress with complete accuracy.

The receiver uses signals from GPS satellites to determine precise machine positioning. Two receivers are used to capture and collect satellite data—one located at a stationary spot on the landfill site, and another located on the machine. Signals from the ground-based reference station and on-board computer are used to remove errors in satellite measurements for centimeter accuracy.

The CAES-enabled machine is driven over the site to create a digital terrain design file. Using the radio network and office software, landfill terrain data is transmitted from the machine to the landfill office. Landfill managers can then send the work plan from the office to the in-cab display to show operators the work to be done.

The in-cab display provides the operator with an overhead and cross-sectional three-dimensional surface view of the color-coded work plan and precise machine location. The software continuously updates terrain and machine position information as the machine traverses the site.

CAES gives the operator the ability to control grade by monitoring progress on the in-cab display, which shows a graphical representation of lift thickness and compaction density. Cut/fill numbers are displayed in real-time as the machine moves across the site, which allows the operator to know precise elevation, material spread, compaction passes, and required cut or fill at any point on the job.
The compactor display shows colored grids representing the number of compaction passes the machine has made across each area. As the compactor wheel travels over an area, the screen changes color to acknowledge the pass. Green areas indicate when optimum compaction has been reached. The system also monitors thick lift information and visually displays when a lift exceeds maximum site parameters.

In tractor, scraper and motor grader applications, the color display graphically shows the operator cut, fill, and grade work to be done according to plan. As the machine works, the screen changes color. Green indicates when the operator has achieved plan grade.

By providing immediate feedback on the accuracy of each pass, CAES operators have the information and confidence they need to work more efficiently, productively and profitably.

**On-Board Components**

**Communications Radio.** The rugged radio, mounted on the roof of the machine, is used for transmitting, repeating and receiving real-time data from GPS receivers. The radio broadcasts real-time, high-precision data for GPS applications. Under normal conditions, the 900 MHz radio broadcasts data up to 10 km (6.2 miles) line-of-sight. Coverage can be enhanced with a network of repeaters, which allows coverage over a broader area. Optimized for GPS with increased sensitivity and jamming immunity, the radio features error correction and high-speed data transfer, ensuring optimum performance. A 450 MHz radio solution is also available.

**GPS Antenna (L1/L2).** The dual frequency external antenna, mounted on the roof of the machine and reference station, is used to pick up the signals from the GPS satellites to determine the machine’s position for high precision, real-time machine guidance and control. A low-noise amplifier provides sensitive performance in demanding applications. The compact, low profile design and sealed housing ensure reliable performance in harsh weather conditions.

**GPS Receiver.** The dual frequency real-time kinematic (RTK) GPS receiver is used to send and receive data simultaneously across the radio network. The system computes differential corrections for real-time positioning with centimeter accuracies, to ensure precise machine guidance and control.

**CAES Touch Screen Display.** The in-cab graphical display provides real-time operating information to the operator. Designed for simple operation, the 264 mm (10.4 in) custom configurable, integrated touch screen display allows operators to easily interface with the CAES system. The display utilizes the latest infrared touch and transflective backlight technology for superior viewing in bright light conditions and a broad-range dimmable backlight for viewing in low light conditions. Designed for reliable performance in extreme operating conditions, the unit is guarded against shock and sealed to keep out dust and moisture.
Off-Board Components

GPS Technology. Global Positioning System (GPS) technology uses 24+ satellites that orbit above the earth and constantly transmit their positions, identities and times of signal broadcasts to earth-based satellite sensors. The GPS receiver is an electronic box, which measures the distance to each visible satellite from an antenna on the ground. Through trilateratization, the receiver determines where the satellite is in respect to the center of the earth. The GPS receiver uses its own position and GPS satellite positions to calculate errors and corrections for computing exact location and precise positioning with centimeter accuracy.

GPS Reference Station. A GPS reference station is used to achieve the centimeter level accuracy needed in a landfill application. The reference station sends GPS information over a radio link to the GPS receiver on the CAES-enabled machine. The receiver combines the information with its own observations to compute precise positioning.

Radio Network. The radio network for CAES has two channels. GPS correction data is transmitted over one channel, while the other channel is used to send site planning and production data to the machine and from the machine back to the site office. By utilizing the same radio as a repeater the range can be extended to provide seamless coverage around local obstacles such as hills or large buildings. Up to four radio repeaters may be used to provide extended coverage.

Landfill Planning Software. Site planning and surveying begins with the landfill planning software. CAES is compatible with most third party CAD planning software packages. Data formats used between the CAES software and the planning software are industry standard .DXF and ASCII.

CAESOffice™. The powerful Caterpillar-designed CAESoffice software enables landfill management to monitor CAES-equipped machines and work progress throughout the site in near real-time. The data is stored in a database format for easy customized access, reporting and editing.

METSmanager. This software package allows for integration of the landfill planning system and the machine. It provides the user interface for CAES and controls all communications over the wireless radio network. METSmanager reads design files in standard .DXF formats, converts them to CAES format (.CAT), and sends the design files to the on-board display on the machine over the radio network. This program continually updates the site model by regularly requesting data transmissions from the machine to the office.

- File Window. Displays design files (.DXF) created using the site planning package, and holds application configuration files for GPS receivers and files converted from .DXF to the CAES on-board software format (.CAT).
- Machines Window. Shows icons of each machine equipped with CAES on-board software. Allows multiple machines to be monitored at the same time.
- Messages Window. Contains a list of recent error, warning, confirmation, or information messages generated by METSmanager.
- Communications Queue Window. Lists all file transmissions scheduled to occur over the radio network and displays transmission status for all files.
Specifications

TC500B Communications Radio
- Technology: Spread spectrum
- Modes: Base, repeater, rover
- Optimal Range: 10 km (6 miles), line-of-sight
- Typical Range: 3-5 km (2-3 miles) varies w/terrain and operating conditions.
- Repeaters may be used to extend range
- Frequency Range: 902-928 MHz
- Networks: Ten, user selectable
- Transmit Power: Meets FCC requirements, 1 watt max.
- License Free (U.S. and Canada)
- Wireless Data Rates: 128 Kbps³
- Operating Temperature: 
  -40°C to 70°C (~-40°F to 158°F)
- Storage Temperature: 
  -40°C to 85°C (~-40°F to 185°F)
- Humidity: 100%
- Sealing: Exceeds MIL-STD-810E, sealed to ±4.5 kPa (±5 psi), immersible to 1 m (39 in)
- Vibration: 8 gRMS, 20-2000 Hz
- Operational Shock: ±40 g, 10 msec
- Survival Shock: ±75 g, 6 msec
- Electrical Input: 10.5 to 20V DC
- Nominal Current: 250 mA (3 W)
- Transient Current: 1000 mA (12 W)
- Protection: Reverse polarity
- Control Interface: SAE J1939 CAN
- Configuration: RS-232 Serial connection
- Operating Temperature: 
  -20°C to 60°C (~-4°F to 140°F)
- Humidity: 100%
- Operational Vibration: 3 gRMS
- Survival Vibration: 6.2 gRMS
- Operational Shock: ±40 g
- Survival Shock: ±75 g
- Electrical Input: 12/24V DC, 9 watts
- Height: 5.1 cm (2.0 in)
- Width: 14.5 cm (5.7 in)
- Depth: 23.9 cm (9.4 in)
- Weight: 1.0 kg (2.25 lb)

MS840 GPS Receiver
- Tracking: 9 channels L1 C/A code, L1/L2 full cycle carrier, fully operational during P-code encryption
- Signal Processing: Supertrak multibit technology, Everest multipath suppression
- Positioning Mode:
- Synchronized RTK: 1 cm + 2 ppm horizontal accuracy/2 cm + 2 ppm vertical accuracy, 300 ms latency, 5 Hz std. maximum rate
- Low Latency: 2 cm + 2 ppm horizontal accuracy/3 cm + 2 ppm vertical accuracy, <20 ms latency, 20 Hz maximum rate
- DGPS: <1m accuracy, <20 ms latency, 20 Hz maximum rate
- Range: Up to 20 km from base for RTK
- Communication: 3x RS-232 ports, baud rates up to 115,200
- Control Interface: SAE J1939 CAN
- Emissions and Susceptibility: CE compliant, exceeds ISO 13766
- Input Connector: 8-pin
- Network Connector: 8-pin
- Height: 230 mm (10 in)
- Width: 85 mm (3.4 in)
- Weight: 0.9 kg (2.0 lb)

Radios outside of U.S. and Canada operate on different frequencies. Please contact your Cat Dealer for specifics.

L1/L2 GPS Antenna
- Operating Temperature: 
  -40°C to 70°C (~-40°F to 158°F)
- Storage Temperature: 
  -55°C to 85°C (~-67°F to 185°F)
- Height: 151 mm (6 in)
- Width: 330 mm (13 in)
- Depth: 72 mm (2.8 in)
- Weight: 1.695 kg (3.8 lb)

CAES Touch Screen Display
- LCD Display: 264 mm (10.4 in)
- 640 x 480 transflective color VGA
- Buttons: touch screen
- Touch Screen: 3.17 mm (0.125 in) resolution infrared high light rejection
- Back Light: 200 cd/m², 200:1 dimming ratio
- Processor: Intel Pentium CPU
- Memory: 64 MB Ram
- Solid State Disk: Internal 128 MB, external compact flash

Customer Support. For over 25 years, Caterpillar has been providing electronic and electrical components and systems for the earthmoving industry – real world technology solutions that enhance the value of Cat products and make customers more productive and profitable. Your Cat Dealer is ready to assist you with matching machine systems to the application or obtaining responsible, knowledgeable support. For additional information, please contact us at LANDFILLGPS@CAT.com
Computer Aided Earthmoving System for Landfills

Landfill Compactors
Track-Type Tractors
Wheel Tractor Scrapers
Motor Graders