U.S. Department of Energy
200 Grand Avenue
Grand Junction, CO 81501

March 3, 2008

Mr. Myron Fliegel
U.S. Nuclear Regulatory Commission
Mail Stop T7J8
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2747

Subject: Transmittal of the Moab UMTRA Project *Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site* (RAP)

Dear Mr. Fliegel:

The U.S. Department of Energy (DOE) is pleased to present you with five (5) copies of the Final RAP for the Moab Project. All comments received from the Nuclear Regulatory Commission (NRC) have been incorporated into the RAP and it is being submitted for NRC's review and future concurrence. The RAP is an eight-binder document consisting of the Remedial Action Selection (RAS) Report and the supporting calculations, which are contained in the following binders:

Binder	Title	Addendum/Attachment
1	Remedial Action Selection	
2	DOE Responses to NRC Comments	Addendum A
	Final Design Specifications	Addendum B
	Final Design Drawings	Addendum C
	Final Design Calculations	Addendum D
	Remedial Action Inspection Plan	Addendum E
3	Draft RAP Disposal Cell Design Calculations	Attachment 1
4	Geology	Attachment 2
5	Ground Water Hydrology	Attachment 3
6	Water Resources Protection	Attachment 4
7	Field and Laboratory Results, Vol. I	Attachment 5
8	Field and Laboratory Results, Vol. II	Attachment 5

The RAS provides a summary level description of the remedial action and a discussion of technical findings leading to the conclusion that the remedial action is consistent with the Environment Protection Agency (EPA) standards for stability, radon control, water resource protection, and site cleanup.

Binders 3 through 8 are supporting information that has not changed since submittal of the Revised Draft RAP in June 2007. At this point we have only included new cover and spine, title page, and a cross-reference guide that can be inserted in the existing copy of Attachment 1. The cross-reference guide would also need to be replaced in Binders 4 through 8. If this is not acceptable or you can't account for five copies and would like us to produce and send any binder/attachment, let us know and we would be happy to produce any document you request. The complete set is included on the CD provided with the hard copies of Binders 1 and 2.

DOE is confident that the RAP will provide the information needed to demonstrate to the NRC that the Crescent Junction Disposal Site is an excellent location for the long-term disposal of the Moab uranium mill tailings, and the DOE design will meet the long-term engineering design life of 1,000 years without reliance on active maintenance as required by UMTRCA and EPA cleanup standards.

DOE has scheduled the milestone for NRC concurrence to be by July 28, 2008. If you have any questions, please call me at (970) 257-2115 or Joel Berwick of my staff at (435) 719-2820.

Sincerely,

Donald R. Metzler
Federal Project Director

cc w/enclosure:
S. Lipstein, EM-CBC (CD only)

cc w/o enclosure:
Cynthia Anderson, EM-3 (e)
Joel Berwick, EM-3.3(e)
Jeff McMillan, EM-3.2(e)
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Marjorie Oaks, RAC (e)
Project File MOA 2.12 (C. Smith)

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DOE–EM/GJ1547

Office of Environmental Management – Grand Junction

UMTRA Project

Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

February 2008

U.S. Department of Energy

Office of Environmental Management

Work Performed Under DOE Contract No. DE–AT30–07CC00014 and No. DE–ATDE–AC01–02GJ79491
for the U.S. Department of Energy Office of Environmental Management.

DOE–EM/GJ1547

Moab UMTRA Project

Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

Remedial Action Selection Report

February 2008
Revision 1

Work Performed by Energy*Solutions* Federal Services under DOE Contract No. DE–AT30–07CC00014 and S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491 for the U.S. Department of Energy Office of Environmental Management, Grand Junction, Colorado

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Addendums

Attachments
(Previously Provided in the Draft RAP)

Acronyms

AC	Acres
Act	Floyd D. Spence National Defense Authorization Act
ASTM	American Society for Testing and Materials
Atlas	Atlas Minerals Corporation
BLM	Bureau of Land Management
CAES	Computer Aided Earthmoving System
Cc	Compression Index or Coefficient of Consolidation
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter
cm/s	centimeter per second
cm^2/s	centimeter squared per second
CN	curve number
CPT	cone penetrometer test
D_{50}	median particle size
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
e_0	Initial Void Ratio
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FE	floating earthquake
FR	Federal Register
ft	foot/feet
ft^3	cubic foot/feet
ft/s	feet per second
FY	fiscal year
g	standard acceleration of gravity
GCAP	Ground Water Compliance Action Plan
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center-Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center-River Analysis System
K_h	pseudostatic coefficient
km	kilometer
LL	Liquid Limit
m^2	square meter
μR/h	microRoentgen per hour
MCE	maximum credible earthquake
mg/L	milligram per liter
mi	mile
mi^2	square mile
MUSLE	Modified Universal Soil Loss
NAS	National Academy of Sciences
NCEER	National Center for Earthquake Engineering Research
NOAA	U.S. National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NP	Not Performed

NRC	U.S. Nuclear Regulatory Commission
NRCS	U.S. National Resources Conservation Service
NSF	National Science Foundation
NUREG-CR	Publications Prepared by NRC Contractors
pcf	pound per cubic foot
pCi/g	picoCurie per gram
pCi/L	picoCurie per liter
$pCi/m^2/s$	picoCurie per square meter per second
PHA	peak horizontal acceleration
PI	Plasticity Index
PL	Plastic Limit
PMF	probable maximum flood
PMP	probable maximum precipitation
psi	pounds per square inch
RAIP	Remedial Action Inspection Plan
RAP	Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site
RAS	Remedial Action Selection Report
ROD	Record of Decision
RRM	residual radioactive material
RUSLE	Revised Universal Soil Loss
SCS	U.S. Soil Conservation Service
SOWP	Site Observational Work Plan
SPT	Standard Penetration Test
SRP	Standard Review Plan
TAD	Technical Approach Document
Tc	Time of Concentration
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
μR/h	microRoentgens per hour
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
yd3	cubic yard

Executive Summary

Background

The Moab Uranium Mill Tailings Remedial Action (UMTRA) Project is a remedial action being performed by the U.S. Department of Energy (DOE) to relocate uranium mill tailings and other contaiminated materials (residual radioactive material, RRM) from its present location approximately three miles northwest of the city of Moab, Utah, to the Crescent Junction Disposal Site in Utah. The RRM was generated through operations of a uranium processing facility. The Uranium Reduction Company operated the mill from 1956 until 1962 when it was sold to Atlas Minerals Corporation (Atlas). The milling operations ceased in 1984. An interim cover was placed over the RRM as part of decommissioning activities between 1988 and 1995. Atlas declared bankruptcy in 1998, and the property was subsequently designated a Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I site through legislation and DOE was given cleanup responsibility.

Studies were conducted in the early 2000s with an Environmental Impact Statement (EIS) issued in July 2005. The Final EIS established that the preferred alternative for long-term disposal of the uranium mill tailings and associated contaminated materials was relocation to the Crescent Junction Disposal Site. Subsequently, a Record of Decision (ROD) was issued in September of that same year. The remedial action consists of the removal and subsequent relocation of all RRM from the Moab Site to the Crescent Junction Disposal Site. Disposal will consist of constructing an approximately 230-acre engineered cell partially below grade. The cleanup must comply with U.S. Environmental Protection Agency (EPA). Following concurrence by the U.S. Nuclear Regulatory Commission (NRC) of this Final Remedial Action Plan (RAP), construction of the disposal cell is to begin in 2008 (Table 0–1).

Development of the Final RAP

The purpose of the RAP is to document the remedial activities necessary to relocate the contaminated materials from the Moab Processing Site for stabilization at the Crescent Junction Disposal Site. This Final RAP is a compilation of efforts by DOE over the last several years.

The original draft plan was developed under a contract by DOE with S.M. Stoller Corporation. Efforts included development of studies and supporting documents for the selection of the Crescent Junction Site. The work established the geology and seismology of the site, the surface water and ground water hydrology, a conceptual plan for the disposal facility, water resource protection, and the processing site cleanup. The Draft RAP was issued to NRC in 2006. Several meetings to review the plan generated comments and responses. The revised Draft RAP was issued in June 2007 and provided the basis for detailed design and future construction.

This Final RAP was developed under a subsequent DOE contract with Energy*Solutions* Federal Services, Inc. Detailed design has lead to revisions of certain sections of the Draft RAP. The segments establishing the basis of site selection and parameters used in the design have not been revised. The Remedial Action Selection Report (RAS) summarizes the key elements that will ensure compliance with the regulatory requirements at the disposal cell and the former processing site. The RAS sections that were rewritten for the Final RAP include: **4.2** Geotechnical Engineering Evaluation based on the final detailed design of the disposal cell for slope stability, settlement, liquefaction, and cover cracking; **5.0** Radon Attenuation calculations and final design; **6.4** Erosion Protection Design, which now encompasses a "wedge" of protection along the north side of the cell; **6.5** Rock Durability; **6.6** Rock Sources; and **7.0** Disposal Cell Design and Construction Details, which now includes construction details and construction sequencing.

Table 0–1. Moab UMTRA Project Timeline

Uranium Reduction Company Operated Mill	1956 – 1962
Atlas Minerals Corp Operated Mill	1962 – 1984
Decommissioning Activities	1988 – 1995
Atlas Declares Bankruptcy	1998
UMTRCA Title I Site Amended to Include Moab Site	Oct 2000
DOE Assumes Responsibility for Cleanup	2001
National Academy of Sciences Review and Recommendation	2001 – 2002
Notice of Intent in *Federal Register* to Prepare Environmental Impact Statement (EIS)	Dec 2002
EIS Issued	Jul 2005
Record of Decision	Sep 2005
Draft RAP	Aug 2006
Revised Draft RAP Issued	Jun 2007
Final RAP Issued	Feb 2008
Crescent Junction Disposal Cell Construction Begins	2008 –

The following is a brief description of what is found in each section of the RAS:

Section 1.0 provides the background, standards, and collateral documents. Two tables contain a list of the contents of Addendums A through E and Attachments 1 through 5.

Section 2.0 presents the data and analyses that show that DOE has adequately characterized the disposal site regarding the impacts of geologic conditions on the long-term performance of the cell. Geologic, geomorphic, and seismic conditions at the site are analyzed and results are presented.

Section 3.0 consists of characterizing the physical and geochemical properties of the ground water hydrogeology units and documents the water use at the disposal site.

Section 4.0 presents the geotechnical engineering aspects of the remedial action. It includes geotechnical investigations at both the disposal site and at the Moab tailings pile and engineering evaluations of the disposal cell's slope stability, settlement, liquefaction potential, and cover cracking.

Section 5.0 covers radon emanation from the cell.

Section 6.0 presents information on surface water hydrology and erosion protection. Included are the hydrologic description of the area, the probable maximum precipitation and probable maximum flood, infiltration losses, water surface profiles and channel velocities, and the details on the erosion protection for the final design of the cell. Rock durability and potential sources of rock are also in this section.

Section 7.0 provides the disposal cell final design and construction details. Construction of the cell will be performed in stages. The sequencing of the construction activities and testing and inspection are also presented in this section.

Section 8.0 presents the water resources protection strategy for the disposal cell.

Section 9.0 provides information on the radiological cleanup at the Moab Processing Site. Site characterization, standards for cleanup, and verification of cleanup are included. A final decision regarding the process site ground water cleanup approach will be deferred until a later date and documented in a subsequent Ground Water Compliance Action Plan.

Supporting Documents

Documents directly supporting this Final RAP in regards to final design and remediation are contained in **Addendum A through E.** These include DOE responses to NRC comments, final design specifications, drawings, and calculations and the Remedial Action Inspection Plan, which describes the quality assurance testing during field construction.

Those documents that supported the Revised Draft RAP are included as the original **Attachments 1 through 5.** These documents have been previously submitted to NRC and are referenced in this Final RAP.

End of current text

1.0 Introduction

The Uranium Mill Tailings Radiation Control Act (UMTRCA) (Title 42 *United States Code* Section 7901 et seq.) was passed in 1978 in response to public concern regarding potential health hazards of long-term exposure to radiation from uranium mill tailings. Title I of UMTRCA provides for remediation of abandoned uranium mill tailings sites and associated vicinity properties by the U.S. Department of Energy (DOE). DOE is required to select and perform remedial actions in accordance with standards set by the U.S. Environmental Protection Agency (EPA) (Title 40 *Code of Federal Regulations* Part 192 [40 CFR 192], "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings") and with the concurrence of the U.S. Nuclear Regulatory Commission (NRC). The selected remedial action is documented by DOE in this *Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site* (RAP), which is submitted to NRC for concurrence with the remedial action. NRC subsequently licenses the completed disposal site.

In October 2000, the Floyd D. Spence National Defense Authorization Act (Act) for fiscal year (FY) 2001 (Public Law 106-398) amended UMTRCA Title I (which expired in 1998 for all other sites except for ground water remediation and long-term radon management), giving DOE responsibility for remediation of the Moab, Utah, Processing Site. That Act also mandated that the Moab Processing Site be remediated in accordance with UMTRCA Title I "subject to the availability of appropriations for this purpose" and required that DOE prepare a remediation plan to evaluate the costs, benefits, and risks associated with various remediation alternatives. The Act further stipulated that the draft plan be presented to the National Academy of Sciences (NAS) for review. NAS was directed to provide "technical advice, assistance, and recommendations" for remediation of the Moab Processing Site. Under the Act, the Secretary of Energy was required to consider NAS comments before making a final recommendation on the selected remedy.

The DOE Preliminary Plan for Remediation (DOE 2001) for the Moab Site was completed in October 2001 and forwarded to NAS. On June 11, 2002, after reviewing the draft plan, NAS provided a list of recommendations for DOE to consider during its assessment of remediation alternatives for the Moab Site. On December 20, 2002, DOE published in the *Federal Register* (FR) a Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for the Moab Site remediation (67 FR 77969). As stated in the NOI, the EIS takes the place of a final plan for remediation for the purpose of supporting decision-making for remediation of the Moab Site. DOE has addressed the NAS recommendations in its internal scoping, in the EIS (DOE 2005), and in supporting documents.

The Record of Decision (ROD) (70 FR 55358, September 21, 2005) detailed the selected alternative for surface remediation as removal of RRM to a disposal cell to be constructed near Crescent Junction, Utah (see further discussion in Section 1.1.3). Rail was selected as the primary mode of transportation for RRM between the Moab Site and Crescent Junction Site.

1.1 Site Background

1.1.1 Location

The Moab Processing Site is located approximately three miles northwest of the city of Moab, in Grand County, Utah, adjacent to the Colorado River (Figure 1–1).

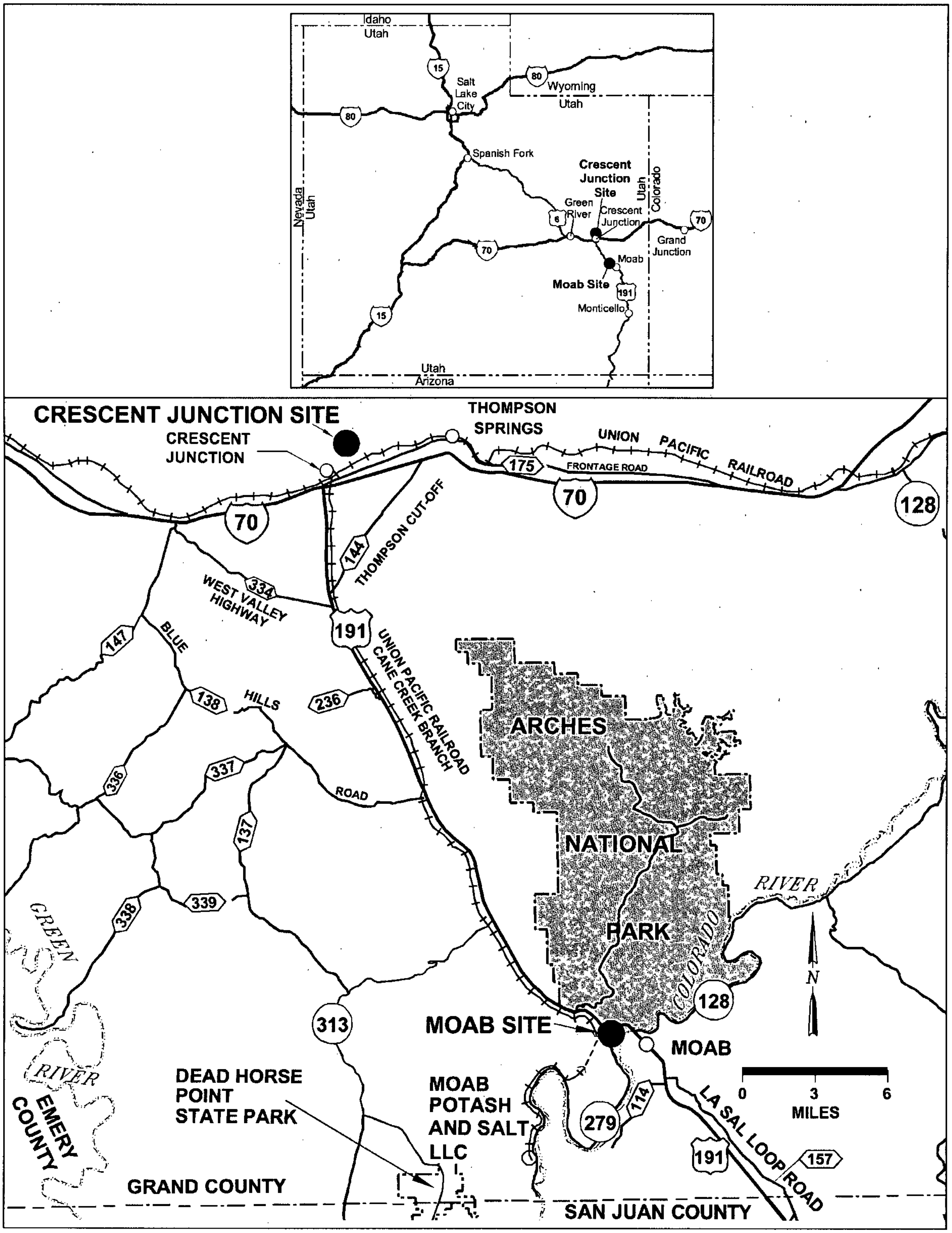

Figure 1–1. Location of the Moab and Crescent Junction Sites in Grand County, Utah

The processing site is on the Moab 7.5-minute topographic quadrangle map in Sections 27 and 28, T25S, R21E, and is shown on the 2005 aerial photograph in Figure 1–2.

The Crescent Junction Disposal Site is located approximately 31 miles north of the Moab Site, and approximately one mile northeast of Crescent Junction, also in Grand County, Utah (Figure 1–1). The disposal site is in a non-populated area just north of Interstate Highway 70 on the Crescent Junction 7.5-minute topographic quadrangle map in Sections 22, 23, 26, and 27, T21S, R19E. The Crescent Junction Disposal Site and surrounding area are shown on the 2005 aerial photograph in Figure 1–3. DOE requested a 5-year temporary withdrawal of approximately 2,300 acres of public domain land near Crescent Junction for the construction of the disposal cell and a buffer zone ("withdrawal area"). The disposal cell footprint occupies only a small portion of the entire temporary withdrawal area (Figure 1–3). An application to transfer 500 acres of the withdrawal area property from U.S. Bureau of Land Management (BLM) to DOE is pending.

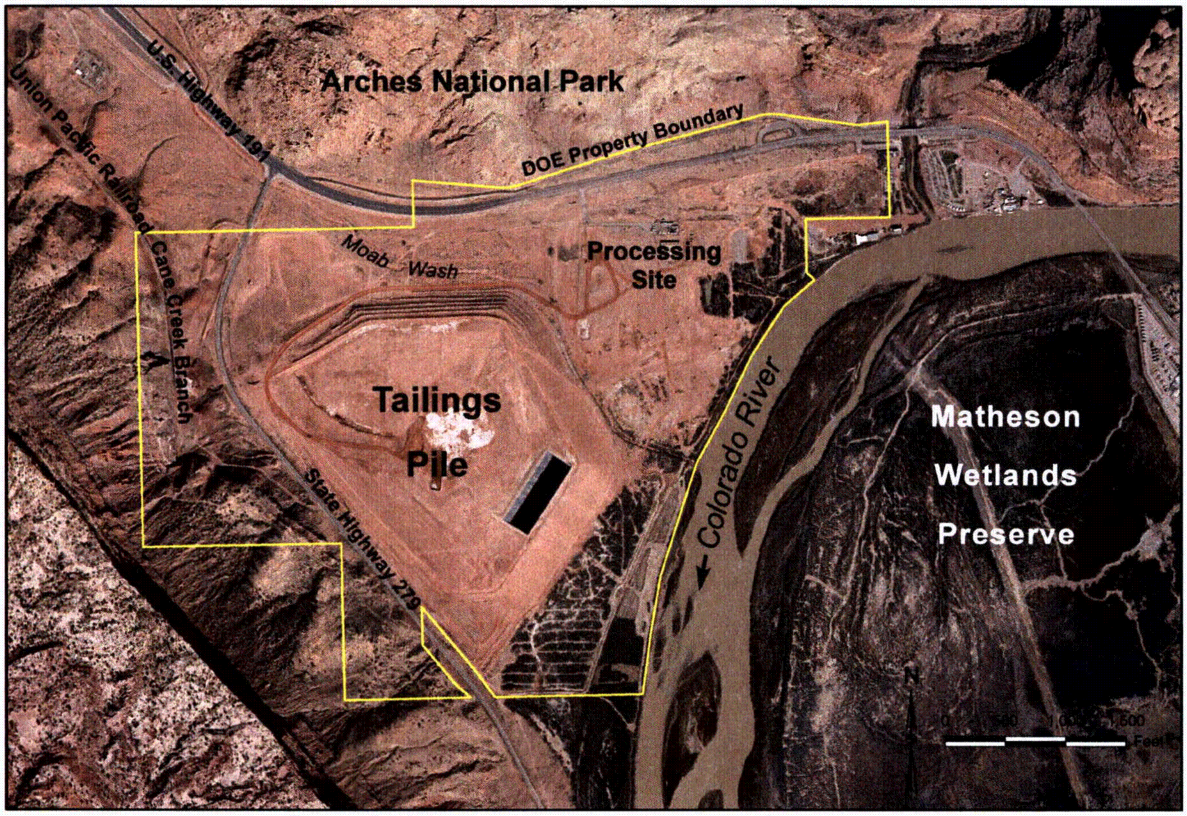

Figure 1–2. Aerial Photograph of the Moab Site

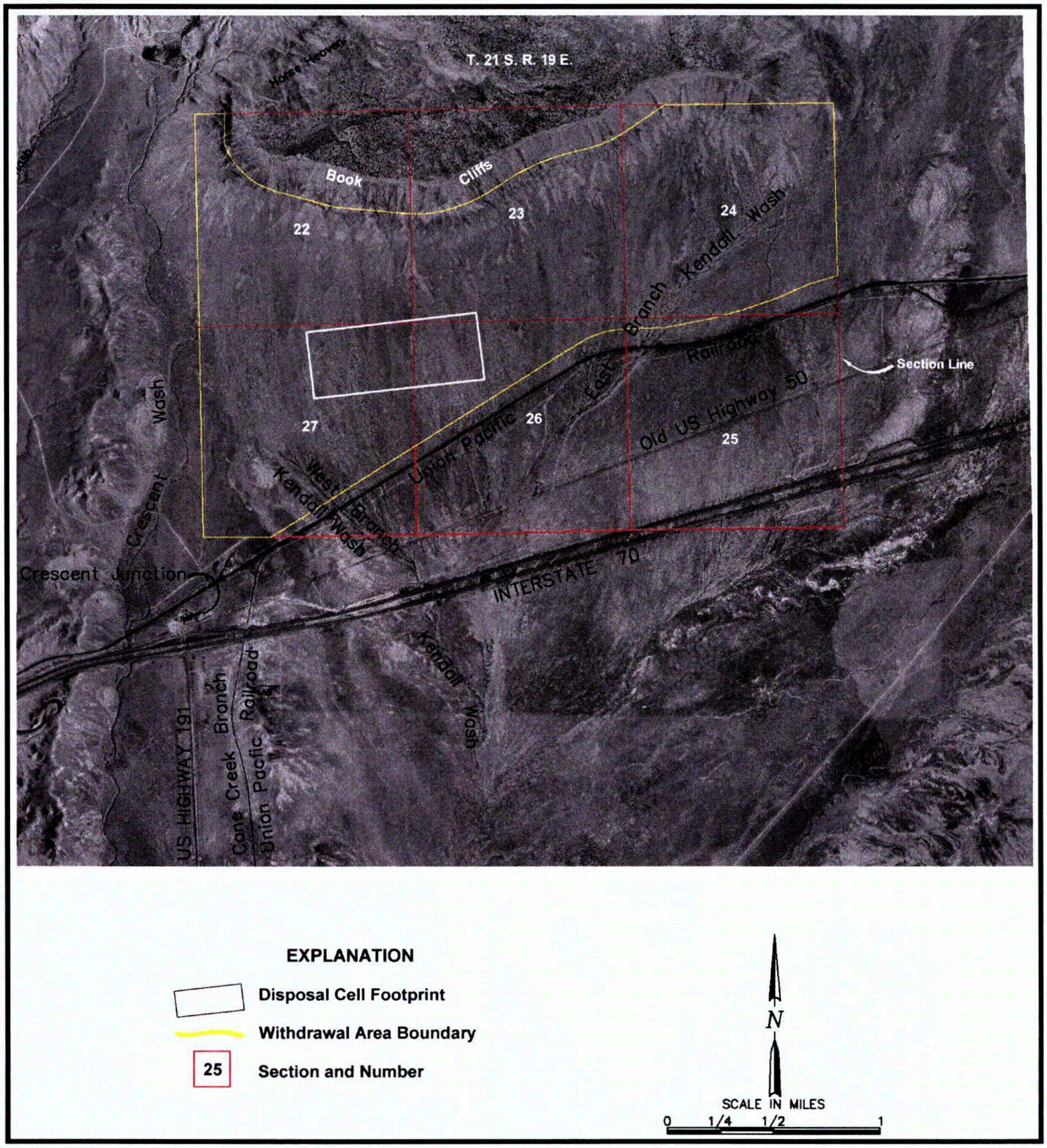

Figure 1–3. Aerial Photograph of the Crescent Junction Disposal Site and Surrounding Area

1.1.2 Site History

The Moab uranium processing facility was constructed in 1956 by the Uranium Reduction Company, which operated the mill until 1962 when the assets were sold to the Atlas Minerals Corporation (Atlas). Uranium processing operations continued under Atlas until 1984. When the processing operations ceased in 1984, the mill had accumulated uranium mill tailings in an unlined impoundment in the floodplain of the Colorado River. The present tailings pile in the west part of the processing site covers approximately 130 acres, is about 0.5 miles in diameter, 94 feet (elevation 4,076 feet) at its highest point above the surrounding ground, and is about 750 feet west of the Colorado River (Figure 1–2). Atlas placed an interim cover over the tailings pile as part of decommissioning activities ongoing between 1988 and 1995.

In 1996, Atlas proposed to reclaim the tailings pile for permanent disposal in its current location. Atlas declared bankruptcy in 1998 and subsequently NRC appointed PricewaterhouseCoopers as the Trustee of the Moab Mill Reclamation Trust and licensee for the site. Subsequently, the Act for FY 2001 mandated that the NRC license for the materials at the Moab Site be terminated and that title and responsibility for cleanup be transferred to DOE by October 31, 2001. DOE assumed full cleanup responsibility for the site during FY 2001.

1.1.3 Remedial Action

Based on the process and evaluation documented in the Final EIS (DOE 2005) for the Moab Site, DOE determined that its preferred alternative for long-term disposal of RRM from the Moab Processing Site was relocation predominantly by rail to the Crescent Junction Disposal Site (Figure 1–1).

The Crescent Junction Site was selected as the preferred off-site disposal location because it has (1) the longest isolation period (time in which contaminants could reach the ground water); (2) the lowest land-use conflict potential (although DOE would need to work with holders of existing oil and gas leases to mitigate any possible impacts); (3) the shortest haul distance from the rail unloading facility into the disposal cell, reducing the size of the radiological control area; and (4) flat terrain, making operations easier and safer.

The tailings pile was constructed with five terraces and consists of an outer compacted embankment of coarse tailings, an inner impoundment of both coarse and fine tailings, and an interim cover of soils taken from the site outside the pile area. Debris from dismantling the mill buildings and associated structures was placed in an area at the south end of the pile and covered with contaminated soils and fill. Radiation surveys indicate that some soils outside the pile also contain radioactive contaminants at concentrations above EPA standards in 40 CFR 192 (see Section 9.1).

Besides tailings, contaminated soils, and debris, other contaminated material requiring cleanup include ponds used during ore-processing activities, disposal trenches, other locations used for waste management during mill operation, and buried septic tanks that are assumed to be contaminated. DOE estimates that total RRM at the Moab Site and vicinity properties has a weight of approximately 16 million tons and a volume of approximately 12 million cubic yards (yd^3). Evidence indicates that historical building materials may contain asbestos.

The remedial action consists of the removal and subsequent relocation of all RRM to the Crescent Junction disposal cell. Essentially all RRM will be placed in containers for transport to the disposal site by either rail or truck. Oversize material will be transported via a secure manner.

Disposal will consist of constructing an approximately 230-acre engineered cell partially below grade. The disposal cell is generally rectangular in shape. The cell is designed for two-thirds of the RRM to be below grade and the remainder above grade. The depth of the cell excavation is based on keying into the weathered Mancos Shale bedrock at least two feet and reusing the shale (after conditioning) to construct the radon barrier. Excavated material will be used as material for construction of the disposal cell's exterior berms, interim cover, and freeze-thaw layer, and will be used to construct the protective wedge to the north of the disposal cell.

1.2 EPA Standards

As required by UMTRCA, remedial action at the site must comply with regulations established by EPA in 40 CFR 192, Subparts A-C. The regulations provide standards for both disposal and cleanup. Disposal and ground water protection standards apply at the disposal site (Crescent Junction); cleanup standards for soil and ground water apply at the processing site (Moab). EPA disposal and ground water protection standards in 40 CFR 192 specify that control of RRM and its listed constituents shall be designed to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

Additionally, as described in the Standard Review Plan (SRP) for inactive uranium mill tailings (NRC 1993), DOE must meet the following basic requirements to receive NRC's concurrence on DOE's proposed remedial action:

- There must be reasonable assurance of compliance with the EPA control requirements of 40 CFR 192 for durability of stabilization and control of radon, and protection of ground water resources in the disposal cell area; and
- There must be reasonable assurance of compliance with the EPA requirements in 40 CFR 192 for cleanup of the processing site.

This RAP summarizes the key elements that will ensure compliance with regulatory requirements at the disposal cell and the processing site. More detailed discussion of compliance with ground water requirements at the processing site is found in the Site Observational Work Plan (SOWP) (DOE 2003). It is anticipated that the final remedial action plan for ground water cleanup at the Moab Site will be submitted to NRC in FY 2011.

1.3 Scope, Content, and Organization

The purpose of the RAP is to document the remedial activities necessary to relocate the contaminated materials from the Moab Processing Site for stabilization at the Crescent Junction Disposal Site. This involves assessment of contaminated materials at the Moab Processing Site and design of the transportation system to get materials to the disposal site. It also involves characterization of the Crescent Junction Disposal Site, design and implementation of the disposal system, and protection of ground water resources at the disposal site.

This RAP provides a summary level description of the remedial action and a discussion of technical findings leading to the conclusion that the remedial action is consistent with the EPA standards for stability, radon control, water resources protection, and site cleanup. An extensive amount of data and supporting information have been generated that cannot all be incorporated into this single report. Pertinent information, design details, drawings, calculations and data are included in the RAP addendums and Draft RAP attachments.

Portions of the information in this RAP were presented by DOE to NRC during meetings held in April, June, and December 2006. Additional meetings in September and November 2007 were held with NRC to update them on design details as they were being developed and to discuss outstanding issues.

Comments received as a result of those meetings and from NRC review of the Revised Draft RAP submitted in August 2006, and the Revised Draft RAP submitted in June 2007, have been incorporated into this report. A comment resolution/response is included as Addendum A to this RAP and explains how each comment was resolved.

The RAP consists of the following addendums that contain the details for the final design (drawings, specifications, and calculation sets) and attachments from the Revised Draft RAP:

- Addendum A – DOE Responses to NRC Comments
- Addendum B – Final Design Specifications
- Addendum C – Final Design Drawings
- Addendum D – Final Design Calculations
- Addendum E – Remedial Action Inspection Plan (RAIP)

- Attachment 1 – Draft RAP Disposal Cell Design Calculations
- Attachment 2 – Geology
- Attachment 3 – Ground Water Hydrology
- Attachment 4 – Water Resources Protection
- Attachment 5 – Field and Laboratory Results (two volumes)

Tables 1–1 and 1–2 list the items contained within each RAP addendum and attachment.

1.4 Collateral Documents

The EIS for the Moab Site (DOE 2005) describes existing conditions at the site, the proposed remedial action, the alternatives to the proposed action, and the environmental impacts of the proposed action. Details are in the EIS and are not reported in this RAP. The SOWP (DOE 2003) assesses ground water conditions at the Moab Processing Site and provides alternatives for ground water cleanup and compliance with the EPA ground water protection standards in 40 CFR 192. Ground water restoration is not a part of this RAP. An interim remedial action has been implemented with a final action to be proposed to NRC in FY 2011.

The Technical Approach Document (TAD) (DOE 1989) is an additional supporting document that describes technical approaches and procedures used on the project. It includes discussions of major technical areas, design considerations, surface water hydrology and erosion control, geotechnical aspects of disposal cell design, radiological issues, and protection of ground water resources. The Technical Approach to Groundwater Restoration (DOE 1993) provides general technical guidance to implement the ground water restoration phase at the processing site.

Table 1–1. Contents of Final RAP Addendums

Addendum A – DOE Responses to NRC Comments	
April 2006	NRC Comments and DOE Responses, April 2006 Meeting
June 2006	NRC Comments and DOE Responses, June 2006 Meeting
February 2007	NRC Comments and DOE Responses, February 2007 Request for Additional Information
September 2007	NRC Comments and DOE Responses, September 2007 Open Issues Meeting
Addendum B – Final Design Specifications	
Number	**Title**
31-00-00 R1	Earthwork
31-00-20 R1	Placement and Compaction of Tailings and Interim Cover
31-00-30 R1	Placement and Compaction of Final Cap Layers
31-32-11 R1	Surface Water Management and Erosion Control
32-11-23 R1	Aggregate and Riprap
Addendum C – Final Design Drawings	
Number	**Title**
E-02-C-100	Overall Site Plan/Key Plan
E-02-C-101	Overall Cell Layout Plan
E-02-C-102	Overall Cell Grading Plan
E-02-C-103	Overall Cell Top of Waste Plan
E-02-C-104	Overall Cell Cap Plan/Fencing Plan
E-02-C-105	Rock Cover Plan
E-02-C-300	Disposal Cell Cross Sections
E-02-C-301	Disposal Cell Cross Sections
E-02-C-500	Details – 1
E-02-C-501	Details – 2
Addendum D – Final Design Calculations	
Number	**Title**
C-02	Disposal Cell Erosion Protection
C-03	Wedge Longevity
C-04	Area Between Cell and Wedge
C-05	Radon Barrier Evaluation
C-06	Drainage During First Phase of Construction
C-10	Slope Stability of Crescent Junction Disposal Cell
C-11	Settlement Analysis of Uranium Mine Tailings at Crescent Junction, UT
C-12	Liquefaction Analysis of Uranium Mine Tailings Repository at Crescent Junction, UT
C-13	Frost Penetration Depth at Crescent Junction Disposal Site
C-15	Analysis for Cover Cracking of the Crescent Junction Disposal Cell
Addendum E – Remedial Action Inspection Plan (RAIP)	
Document	Remedial Action Inspection Plan (RAIP)
Attachment 1	Computer Aided Earthmoving System (CAES) For Landfills

Table 1–2. Contents of Draft RAP Attachments

Calculation Cross-Reference Guide		
Location	**Calculation Number**	**Calculation Title**
Attachment 1: Draft RAP Disposal Cell Design Calculations		
Appendix A	MOA-02-08-2006-5-19-01	Freeze/Thaw Layer Design
Appendix B	MOA-02-08-2006-5-13-01	Radon Barrier Design Remedial Action Plan
Appendix C	MOA-02-05-2007-5-17-02	Slope Stability of Crescent Junction Disposal Cell
Appendix D	MOA-02-05-2007-3-16-01	Settlement, Cracking, and Liquefaction Analysis
Appendix E	MOA-02-09-2005-2-08-01	Site Drainage – Hydrology Parameters
Appendix F	MOA-02-06-2006-5-08-00	Crescent Junction Site Hydrology Report
Appendix G	MOA-02-04-2007-5-25-02	Diversion Channel Design, North Side Disposal Cell
Appendix H	MOA-02-08-2006-6-01-00	Erosional Protection of Disposal Cell Cover
Appendix I	MOA-01-06-2006-5-02-01	Volume Calculation for the Moab Tailings Pile
Appendix J	MOA-02-08-2006-5-03-00	Weight/Volume Calculation for the Moab Tailings Pile
Appendix K	MOA-01-08-2006-5-14-00	Average Radium-226 Concentrations for the Moab Tailings Pile
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End of current text

2.0 Geology and Seismology

The objective of this section is to present the data and analyses that show that DOE has adequately characterized the Crescent Junction Disposal Site regarding the impacts of geologic conditions on the long-term performance objectives of the remedial action as defined by 40 CFR 192.02.

EPA standards listed in 40 CFR 192 do not include generic or site-specific requirements for characterization of the geologic conditions at Uranium Mill Tailings Remedial Action (UMTRA) Project Sites. Rather, the standards require the stabilization and control of the tailings to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. For this long-term stability to be achieved, certain geologic performance objectives must be met. An evaluation of the potential geomorphic hazards is required, and DOE will show that potential geomorphic change will not affect the integrity of the disposal cell for its design life. The seismological characterization of the site will provide estimates of earthquake-induced ground accelerations that could occur at the site, as well as the potential for other types of tectonic hazards that could affect disposal cell performance. In addition, geological site characterization must demonstrate that future resource development will not adversely affect the disposal cell stability. Additional criteria that form the basis of the work described in this document and the evaluation of the adequacy of the site and regional geology are in the TAD (DOE 1989).

2.1 Scope of Work

Geologic, geomorphic, and seismic conditions at the site were investigated in detail. Geology was investigated according to procedures and approaches described in the TAD to gather the data specified in the NRC SRP and the Standard Format and Content guide. These investigations included, but were not limited to: (1) the compilation and analysis of published and unpublished geological literature and data; (2) the review and analysis of historical and instrumental seismic data; (3) geological field mapping and observations; (4) review of site-specific subsurface geologic and geotechnical data, including logs and samples from boreholes and coreholes, test pits, and analysis of recent and historical aerial photographs; and (5) studies of previous work. Details of the data gathering, interpretation procedures, and results are in the calculation sets referenced in this section and in Attachment 2.

2.2 Regional Geology

To provide a background for the detailed site geology and subsurface conditions, regional geologic conditions of the Crescent Junction Disposal Site in east-central Utah are described below. Most of this information is from maps and publications referenced in the following sections and in calculation sets in Attachment 2 of the Draft RAP. The site region is considered as the area within a 40-mi radius (based on a relevant seismic attenuation distance) of the disposal site. That area is used in analyzing seismologic stability, but a smaller area is generally discussed with respect to other geologic aspects.

2.2.1 Physiography

The Crescent Junction Site is in the north end of the Canyon Lands section of the Colorado Plateau physiographic province (Figure 2–1). The Canyon Lands section is characterized by deeply incised drainages, isolated mesas, gently dipping bedrock, and anticlines formed by salt intrusion that have been breached in places by erosion to form anticlinal valleys. North of the Canyon Lands section is the Uinta Basin section of the Colorado Plateau; the boundary between the two sections is the Book Cliffs, an erosional escarpment just north of the site. The Uinta Basin section is characterized by a rugged, intricately dissected plateau bounded on the south by sets of cliffs (one of which is the Book Cliffs) that are highly irregular with many salients and canyons (reentrants). Further physiographic subdivisions recognized in the State of Utah place the site in the Mancos Shale Lowland (Figure 2–1). Elevations in the site region range from approximately 3,900 to 12,000 ft.

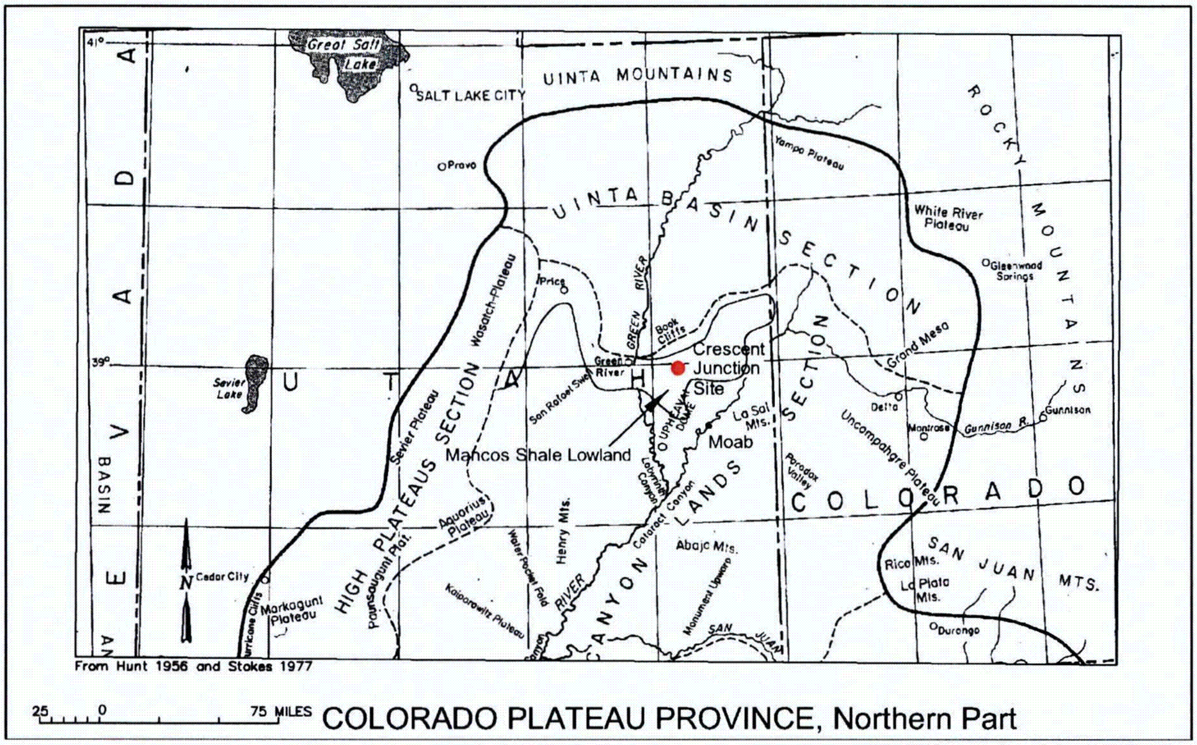


Figure 2–1. Physiographic Setting of the Crescent Junction Site

The main physiographic features of the immediate site area are as follows:

- Type of geomorphic surface that surrounds the site: The surface area of the site is on Crescent Flat—a gently south-sloping area between the base of the Book Cliffs to the north and Interstate Highway 70 to the south.
- General relief and topography of the site: The low-relief surface of Crescent Flat slopes gently southward for approximately two miles, from an elevation of about 5,100 feet to the north to about 4,900 feet to the south. Topography is controlled by the Mancos Shale, which underlies the Mancos Shale Lowland.
- Drainage system: Minor, slightly to moderately incised, ephemeral West and East Branches of Kendall Wash drain the disposal site area. The branches join and drain south into the ephemeral Thompson Wash, which joins ephemeral Tenmile Wash that drains into the

Green River about 25 miles southwest of the disposal site area. Bordering Crescent Flat to the west, Crescent Wash is a larger ephemeral system that drains an approximately 22-square-mile (mi^2) area north of the site in the Book and Roan Cliffs.

- Major regional geomorphic processes: Significant processes are the retreat and rock falls associated with the Book Cliffs escarpment, aggradation across Crescent Flat associated with sheet wash from the base of the Book Cliffs, and incision and migration of minor drainage systems.

Additional details of the regional physiographic setting are in Attachment 2, Appendix C.

2.2.2 Stratigraphy

The regional geologic setting of the Crescent Junction Site is shown in the geologic map of east-central Utah in (Figure 2–2). A 5 to 10-mi-wide swath of outcrop of Mancos Shale of Late Cretaceous age corresponds to the Mancos Shale Lowland and the Crescent Junction Site. Rocks in the Lowland area of the site dip generally northward at low angles of less than 10 degrees toward the Uinta Basin. Regionally, approximately 4,000 feet of continental sedimentary rocks of Mesozoic age underlie the marine Mancos Shale, which also is about 4,000 feet thick. The part of the Mancos Shale underlying the immediate site area is about 2,400 feet thick. Above and north of the Mancos Shale in the Book Cliffs area are continental sedimentary rocks of the Mesaverde Group of Late Cretaceous age. Quaternary material consisting of alluvial and colluvial mud, stream alluvium, pediment-mantle deposits, talus, and colluvium mostly cover the Mancos Shale at the site area.

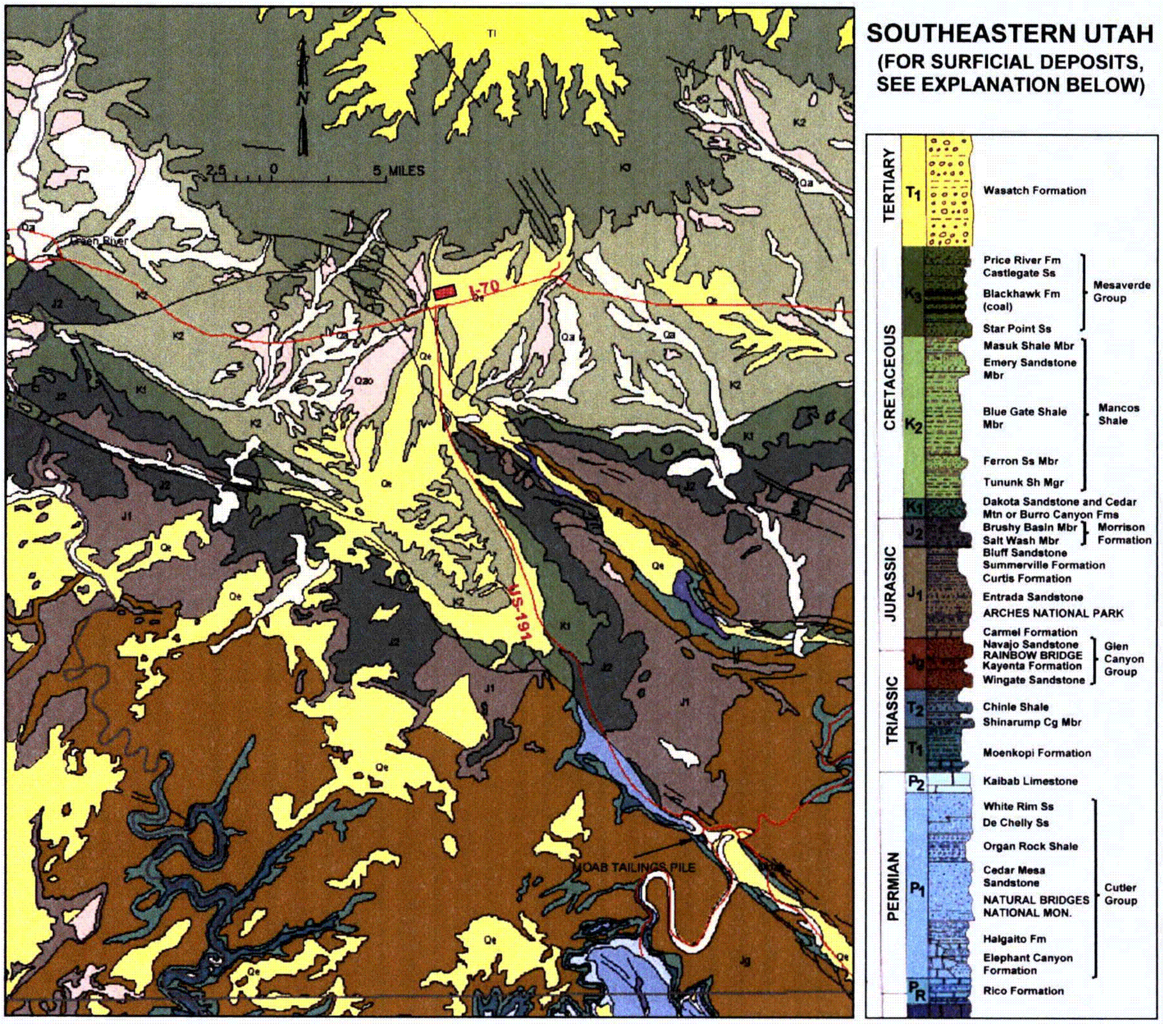
Descriptions and a stratigraphic column of the geologic formations of Mesozoic age that underlie the site and of the Mancos Shale and overlying Mesaverde Group of Late Cretaceous age are in Attachment 2, Appendix A. Also in this calculation set is a description of the unconsolidated Quaternary deposits.

2.2.3 Structural Setting

The Colorado Plateau, an intercontinental subplate with a greater crustal thickness than the adjoining provinces, provides a stable setting for the site. The plateau has been gradually uplifting since the Tertiary Period. Within the plateau, principal structural elements in the site region include the Uinta Basin, Paradox Basin, and Uncompahgre Uplift. The site is near the south edge of the Uinta Basin and in the northwest part of the ancestral Paradox Basin, where salt was deposited in Pennsylvanian time. Northwest-striking anticlines and synclines that formed as a result of movement of the deeply buried salt are in the north part of the Paradox Basin in what is called the Paradox Fold and Fault Belt. Additional description of the structural setting of the site and a map showing the regional structural elements are in Attachment 2, Appendix A.

2.2.4 Seismotectonics

Literature and database searches were the basis for a site-specific evaluation of the seismotectonic stability of the Crescent Junction Site. Results of the evaluation (included in Section 2.4.2) serve as input to the disposal cell design. Data, analyses, and references summarized in this section are included in Attachment 2, Appendixes E and F.



EXPLANATION

CRESCENT JUNCTION SITE
FAULT
HIGHWAY AND NUMBER
I-70

QUATERNARY SURFICIAL DEPOSITS
- Qa ALLUVIUM AND COLLUVIUM
- Qe EOLIAN AND ALLUVIAL DEPOSITS
- Qap OLDER ALLUVIAL DEPOSITS

Figure 2–2. Regional Geology of the Crescent Junction Site

The Crescent Junction Site is in the Paradox Fold and Fault Belt of the Colorado Plateau tectonic province, which is relatively stable according to historical earthquake data and is considered to be inactive under the current tectonic regime. Surrounding tectonic provinces are more active and have higher-magnitude earthquakes. Historical earthquake data were compiled for all surrounding provinces, and literature estimates for maximum earthquakes were obtained for each province.

Data regarding known faults in the expanded study area were assembled. Fifteen faults (or fault zones) were identified as having potential to impact the site. Most of the faults and structural features in the study area are associated with salt deformation, dissolution, and collapse. Some of these structures may have had movement in the Quaternary, but the movement is very slow and unlikely to generate large earthquakes. Of the 15 faults, five were either determined active in the Quaternary or of unknown age. The remaining 10 faults were determined inactive in the Quaternary.

No evidence of faulting in the Crescent Junction area was observed during the photogeologic evaluation and follow-up field investigations. The only faults noted were outside the withdrawal area, which encompasses the Crescent Junction Disposal Site.

Peak horizontal ground acceleration (PHA) maps were obtained for both the United States and the State of Utah. These maps showed a range of estimated PHAs for the Crescent Junction area. Recent U.S. Geological Survey (USGS) maps (Frankel et al. 2002) show the peak acceleration to be 0.045 standard acceleration of gravity (g) with a 10 percent probability of exceedance in 50 years, and 0.12 g with a 2 percent probability of exceedance in 50 years. In contrast, Halling et al. (2002) estimated the PHA for the Crescent Junction Site to be approximately 0.5 g. However, this estimate is based on the assumption that the Tenmile Graben is an active structure, which is contrary to evidence presented by Woodward Clyde Consultants (1996). The seismotectonic study conducted for the nearby Green River, Utah, UMTRA Project Site recommended a design acceleration of 0.21 g based on a magnitude 6.2 floating earthquake (FE) occurring 15 kilometer (km) (9.3 mi) from the site. These literature estimates were considered further in the site-specific evaluation of the site (Section 2.4.2).

2.2.5 Resource Development

Historical geologic resource development and the potential for future development at the Crescent Junction Site and nearby region are evaluated and documented in Attachment 2, Appendix A. Geologic resources evaluated were those that, if exploited, could result in disturbance of the disposal site.

Geologic resources and their development potential identified in the site and nearby region are oil and gas, potash and salt, coal, uranium and vanadium, copper and silver, gold, and sand and gravel. These resources and their development potential are documented in both the Mineral Potential Report for the Moab Planning Area (north part of the Moab District, U.S. Bureau of Land Management) (Tabet 2005) and the Mineral Report on the DOE Proposed Disposal Site (Bain 2005). From those reports and the recent oil and gas leasing and drilling activity near the site, it is likely that the only geologic resources at the site that have moderate to high potential for economic development would be oil and gas.

The construction and presence of an approximately 230-acre disposal cell at the site would not preclude the exploration and development of oil and gas resources. Exploration by directional drilling could evaluate the presence of oil and gas directly beneath the disposal cell. Possible oil and gas production from beneath the disposal site at depths between 4,000 and 11,000 feet would not result in subsidence.

2.3 Site Geology

Bedrock geologic conditions at the site are characterized primarily to provide the basic information required for geotechnical stability evaluations (Section 4.0) and for ground water performance assessments (Sections 3.0 and 8.0). Surficial geologic conditions are characterized to establish the geomorphic history and processes at the site that determine if the long-term stability requirements will be met.

Geologic field investigations at the Crescent Junction Disposal Site included drilling of coreholes and geotechnical boreholes, and excavation of test pits. Ten coreholes were drilled to depths of approximately 300 feet into the Mancos Shale. Core samples were logged in the field using visual soil- and rock-classification procedures, and the coreholes were geophysically logged. One hundred geotechnical boreholes were drilled to depths of as much as 26 feet through the surficial unconsolidated material into the shallow weathered Mancos Shale, with samples logged in the field. Five test pits were dug with a trackhoe to investigate subsurface conditions to depths ranging from 15 to 23 ft. Logs for all subsurface investigations are in Attachment 5, Appendixes A, B, C, and D.

Aerial photographs (including high-altitude vertical and low sun-angle) of the area were produced to analyze structural and geomorphic conditions that may affect the site. Historic aerial photographs dating back to 1944 were also used in the analysis of site conditions. The Photogeologic Interpretation calculation is presented in Attachment 2, Appendix G.

The procedures used to characterize site geology and the details of that site characterization are in Attachment 2, Appendix B. Geomorphologic information is in Attachment 2, Appendixes C, D, and G. Brief descriptions of the salient geologic and geomorphic features are in the following sections.

2.3.1 Bedrock Geology

The site area is underlain by the Mancos Shale of Late Cretaceous age that dips gently (approximately 5 to 6 degrees) northward. The shale forms a broad, east-trending belt immediately south of the Book Cliffs. Topographically, the shale forms badlands that are the lower or buttressing part of the Book Cliffs and the wide expanse of lowlands, or "flats", extend several miles to the south. Total thickness of the Mancos Shale, which generally represents the open-marine mudstones deposited in the Cretaceous Western Interior Seaway, is approximately 3,500 feet in the immediate site area as measured from the top of the Book Cliffs.

Most of the Mancos Shale is a monotonously uniform drab or bluish-gray shale; however, in the site area, which is in the upper third of the formation, an anomalously sandy interval, named the Prairie Canyon Member of the Mancos Shale, represents a period of near-shore deposition. From the sandy (generally very fine-grained) nature of this member, as exposed in a few outcrops, seen in several coreholes and test pits, and expressed as a marked reduction in the gamma ray geophysical log response from coreholes, the thickness of the Prairie Canyon Member in the mapped area is approximately 150 to 200 ft. As much as 150 feet of the Prairie Canyon Member is beneath the north edge of the proposed disposal cell. Underlying and overlying the sandy interval of the Prairie Canyon Member is the Blue Gate Member of the Mancos Shale. The Blue Gate Member consists mainly of open-marine mudstone and shale, with a few thin siltstone layers. In the site area, the Blue Gate Member is divided into lower and upper parts to accommodate the Prairie Canyon Member. Outcrops of both lower and upper parts of the Blue Gate Member are rare—only one of each was found in the mapped area. A thickness of approximately 2,000 feet of lower Blue Gate Member is in the site area. Below the Blue Gate Member are the lowermost members of the Mancos Shale, the Ferron Sandstone Member underlain by the Tununk Shale Member, that combine for an approximate 300 feet to 400 feet thickness. It is therefore estimated that approximately 2,400 feet of Mancos Shale underlies the center of the proposed disposal cell.

Natural fractures are mostly in the top 50 feet of the weathered Mancos Shale bedrock. Below that, only a few fractures are in the competent bedrock, and no natural fractures were seen deeper than 100 feet into the bedrock. Characteristics of the weathered and unweathered zones of both the Prairie Canyon and Blue Gate Members of the Mancos Shale bedrock have been compiled from corehole lithologic logs and rock quality designation data; details are in Attachment 2, Appendix B. Hydrologic and transport properties of the Mancos Shale are discussed in Section 3.3.

No faults or evidence of faults (slickensides on fracture surfaces) were found in the deep coreholes. Additional evidence for lack of faulting in the site area is the continuity of the stratigraphic horizon composed of dolomitic siltstone concretion masses that mark the top of the Prairie Canyon Member. No evidence for displacement is seen along the line where the scattered dolomitic siltstone concretions crop out. Field investigation and aerial photograph interpretation have further ruled out faulting in the area that could impact the disposal site.

2.3.2 Surficial Geology

Nearly all of the disposal cell withdrawal area is covered by unconsolidated Quaternary material. These deposits cover Mancos Shale (Blue Gate or Prairie Canyon Members) bedrock and are typically about 10 feet to 12 feet thick, but can be as much as 25 feet. Most significant of the Quaternary deposits is gray alluvial mud, which consists mostly of silt and clayey silt that represents successive sheet wash deposits from erosion of Mancos Shale along the lower slopes of the Book Cliffs. A small amount of brown, sandy silt of eolian origin is in discontinuous layers in the alluvial mud. Also, sand to gravel to small boulder-sized material is at the base of the alluvial mud in a few swales and washes that were cut into the Mancos Shale bedrock. One such swale, slightly more than 20 feet deep, was found just southeast of the disposal cell footprint. No evidence of ground water was observed in any of the bedrock swales or surface washes.

Surficial deposits have been emplaced in a stable geologic environment mainly by a slow accumulation of material transported during infrequent heavy rainfall episodes from the base and sides of the Book Cliffs along active sheet wash paths. No evidence of faulting or displacement of Quaternary material is seen in the vicinity of the site.

2.3.3 Geomorphology

Results of literature research on the geomorphology of the site indicated that the site appeared to be suitable for disposal of the Moab uranium mill tailings (Attachment 2, Appendix C). Further site-specific field investigations supported this conclusion and showed that the landscape at Crescent Flat is dominated by depositional (or aggradational), rather than erosional (or degradational), processes (Attachment 2, Appendix D).

Geomorphic processes in this area that may affect disposal cell performance include fluvial, mass movement, and eolian. Fluvial processes, related to the drainage system of the withdrawal area and the nearby surrounding area, will have the most significant effect on the site area that includes the proposed disposal cell. The other geomorphic processes investigated—mass movement and eolian—will likely have negligible effects on the disposal cell and nearby area. Mass movement processes of rock fall, landslides, and scarp retreat are confined to the Book Cliffs, which are far enough away (approximately 2,000 feet at the closest point) to not affect the disposal cell. Eolian processes, active in drier times earlier in the Holocene Epoch, are not expressed at the site and apparently will not affect the site unless the climate becomes drier. Fluvial processes are discussed below and the potential for rock falls is considered in the next section on geologic hazards.

Long-term incision advance of the tributaries of the West Branch of Kendall Wash has the greatest potential of fluvial erosion processes to affect the disposal cell. Headward incision northward at a rate measured from historical aerial photographs of an eastern tributary to the West Branch could reach the southwest corner of the disposal cell in about 500 years. Increased flows in the drainage created by channeling of several drainages around the west side of the disposal cell will accelerate headcutting and shorten the time for erosion to reach the disposal cell corner. This drainage path was included in the engineering design of the disposal cell to mitigate this headward erosion.

The tendency of Crescent Wash to migrate eastward toward the disposal cell is low because the wash channel will likely soon follow an incipient cutoff channel, resulting in a straightening of the wash course. Long-term incision advance of a tributary of the West Branch of Kendall Wash could capture the Crescent Wash drainage after approximately 1,600 years. At that time, the high-energy Crescent Wash channel could then be about 1,000 feet west of the disposal cell—probably far enough away not to pose an erosion threat to the cell.

Erosional incision advance of the present East Branch of Kendall Wash resulted in capture of an earlier drainage thousands of years ago. Incision advance of this wash and its tributaries will continue, but this erosion is 0.5 to 1.0 miles or more east of the disposal cell and will not affect the site.

2.3.4 Geologic Hazards

Potential geologic hazards in the vicinity of the disposal site include mass movement processes, such as rock fall, landslides, and scarp retreat. These processes are confined to the Book Cliffs, which are far enough away (approximately 900 feet at the closest point) to not affect the disposal cell. Swelling clay in the Mancos Shale also poses a potential but manageable and acceptable risk, as does the presence of radon in the Mancos Shale. These potential hazards are summarized below and discussed in more detail in Attachment 2, Appendix A.

The Mancos Shale formation can exhibit characteristics of moderate swelling, due to the possible presence within the shale of expansive clays and thin gypsum lenses, which expand when hydrated. Though possible, expansion of the shale is not considered to be problematic for the following reasons:

a) The shale formation has extremely low hydraulic conductivity, and though the top surface of the shale will be wetted during the time when tailings are being placed and later as excess capillary water migrates to and along the cell floor, the water will not migrate very far into the shale formation. The thickness of the shale being wetted is not likely more than 1 to 2 feet and the volume of expansive clay or gypsum in that thin layer of shale cannot expand enough to be of consequence. For example, if two feet of shale is hydrated, and 25 percent of the two feet thickness is expansive material, and the expansive material expands 50 percent (typical for some types of gypsum), the total expansion would be three inches.

b) Minor expansion, if it occurs, will take place when the Mancos shale is initially wetted. At that point, the cell is being excavated and the first layers of tailings are being placed. There will not be anything in place at that point that could be damaged by minor soil movement. Damage from soil expansion and contraction tends to occur when a sensitive structure such as a building or highway undergoes differential movement. The disposal cell is not a sensitive structure, especially in the early stages of cell excavation and tailings placement.

c) Expansion and/or contraction of expansive soils takes place when significant changes in moisture content occur. When moisture content is relatively constant, expansion and/or contraction does not occur. A relatively thin layer of Mancos shale may expand when initially hydrated, but once several feet of tailings have been placed over the shale, the moisture content at the cell floor should remain relatively constant. Whether the cell eventually dries out or has some residual moisture at the cell floor long-term, it should not be subject to moisture fluctuations that would result in significant cycles of expansion and contraction.

Rock-fall debris covers some of the badlands slope as talus along the south side of the 800 foot high Book Cliffs. The dislodged rock is sandstone from the Blackhawk Formation and Castlegate Sandstone, both of the Mesaverde Group, which cap the Book Cliffs. An empirical investigation was conducted to evaluate how far this rock-fall material could run out along the base of the Book Cliffs and if it could affect the disposal cell. Based on two profiles near the northeast part of the disposal cell (closest to the Book Cliffs), and with the source of rock fall starting near the base of the Blackhawk Formation at an elevation of approximately 5,700 ft, the distance from the empirical rock-fall runout limits to the edge of the disposal cell footprint is approximately 2,000 ft. This is far enough north away from the disposal cell and any infrastructure or access roads to not pose a rock-fall hazard. Slow scarp retreat (estimated at five feet per 1,000 years) northward of the Book Cliffs over time will continue to reduce this hazard to the disposal cell.

Landslides, mainly on northerly-facing slopes below the Blackhawk Formation/Castlegate Sandstone cap of the Book Cliffs, are just north of the withdrawal area. In general, these landslides are very old, are no longer active, and apparently formed in much wetter climatic conditions during the Pleistocene. During these wetter conditions, small landslides formed even on the south-facing slopes of the Book Cliffs, where several remnants of inactive landslides remain.

Literature review and site test data indicate that swelling clays if present will not impact performance of temporary structures (such as access roads) and permanent structures (cell embankments and cover). Concerns are described in Attachment 2 Geology and in response to comments Addendum A Response to NRC Comments.

The site area has a moderate to high radon-hazard potential for occurrence of indoor radon based on the geologic factors of elevated uranium concentration in the Mancos Shale, soil permeability, and ground water depth. No permanent structures are planned for the disposal site; therefore, high indoor radon concentration will not be a problem.

2.4 Geologic Stability

This section identifies local geologic and seismic conditions that could affect the geologic stability of the disposal cell and the long-term stability of the landscape environment. This section demonstrates that geomorphic processes will not impact the long-term stability of the disposal cell. Potential geologic events, including seismic shaking, liquefaction, and on-site rupture, are ruled out as disturbing forces on the disposal cell either because they will not occur or because the cell is designed to withstand such geologic occurrences.

2.4.1 Geomorphic Stability

DOE provides evidence of the long-term geomorphic stability of the site in Attachment 2, Appendixes C, D, and G. The landscape is dominated by slow depositional processes. The fluvial-geomorphologic features identified at the site pose little risk to the disposal cell. However, sheet wash coming onto the site from the north will have to be redirected to the west around the disposal cell, and the northward advance of headward incision of the West Branch of Kendall Wash will have to be monitored.

Based on these evaluations, DOE concludes that the site is geomorphically stable and will continue to be so for the performance period of the remedial action.

2.4.2 Seismotectonic Stability

A site-specific analysis determined a maximum credible earthquake (MCE) and a corresponding design acceleration. The MCE for the design earthquake was determined according to the steps in the SRP (NRC 1993). That process is described below with a summary of results. Data and specific methods, calculations, and references used in the analysis are in Attachment 2, Appendix F.

<u>Step 1. Floating Earthquake (FE)</u>

An FE magnitude of 6.2 was considered in the seismotectonic analysis of both the Green River, Utah, and Grand Junction, Colorado, UMTRA Project Disposal Sites. Based on a statistical evaluation using historical earthquake data for the Colorado Plateau, a recurrence rate of having a 6.2-magnitude event within 15 km (9.3 mi) of the site was estimated at 77,000 years. The probability of this magnitude being exceeded within the 1,000-year design life for the disposal cell is one percent. A 6.2 magnitude FE for the site was therefore chosen as a conservative estimate for an MCE. Assuming that an FE of magnitude 6.2 occurs within 15 km (9.3 mi) of the site, the PHA for the site was calculated at 0.22 g. This was used as the point of comparison for the rest of the analysis.

Step 2. MCE Associated with Outlying Tectonic Provinces

Following the methodology in the SRP (NRC 1993), literature MCEs for each of the tectonic provinces surrounding the Colorado Plateau were obtained. An MCE was assumed to occur at a point closest to the site in each province; corresponding PHAs for the site were determined. All of these PHA values for surrounding tectonic provinces were less than that for the Colorado Plateau. Therefore, the FE for the Colorado Plateau of magnitude 6.2 is retained as the design earthquake.

Step 3. Identification and Analysis of Capable Faults

Faults known to be active during the Quaternary Period (Quaternary faults) within the expanded study area (and known faults of indeterminate age) were screened based on lengths and distance from the site to identify actual faults with the potential to generate a PHA of >0.1 g as the result of an MCE. Fifteen faults were further analyzed to determine likelihood of movement and the potential effects at the site. Six faults had PHAs exceeding the FE PHA of 0.22 g. All of these faults were determined to be not active in the Quaternary; and five were determined to be related to salt-dissolution subsidence. None of the six are considered potential design faults. Of the faults considered active in the Quaternary, the highest calculated PHA is 0.13 g. Therefore, the FE for the Colorado Plateau of magnitude 6.2 is retained as the design earthquake.

Step 4. Designation of MCE

The seismotectonic analysis concluded that the greatest impacts at the site would likely come from an FE as opposed to an earthquake generated by a known fault. Therefore an earthquake of magnitude 6.2 occurring at a distance of 15 km (9.3 mi) from the site was recommended as appropriate for the site with a corresponding PHA of 0.22 g.

Specific seismic parameters were used in conjunction with appropriate soil strength parameters, disposal cell geometry, and ground water information to assess slope stability and liquefaction potential.

- Long-term slope stability seismic coefficient is 0.15 (2/3 of PHA).
- Short-term slope stability seismic coefficient is 0.11 (1/2 of PHA).
- Liquefaction analysis: ground surface horizontal acceleration is 0.22 g.

2.5 Geologic Suitability

Based on the site characterization summarized in this section and included in Attachment 2, the details of the Final RAP, and the provisions for stability included in the design of the disposal cell, DOE concludes that there is reasonable assurance that the regional and site geologic conditions have been characterized adequately to meet the requirements in 40 CFR 192.

Results of literature research on geologic and geomorphologic characteristics indicate that the Crescent Junction Disposal Site is apparently suitable for the Moab RRM (Attachment 2, Appendixes A and C). The approximately 2,400 foot thickness of Mancos Shale beneath the disposal cell effectively isolates it from deeper strata that contain ground water (Dakota aquifer). Although faults are present within several miles of the site, they represent adjustments by slow subsidence to the process of dissolution of deeply buried, thick salt deposits. None of the faults appear to have displaced Quaternary surficial deposits, suggesting that significant offset occurred prior to the Quaternary Period.

Geologic investigations in and immediately surrounding the disposal cell footprint found no potential deficiencies in geologic conditions that would adversely affect the geologic suitability of the site. No evidence for faults was seen on the surface or in the subsurface from boreholes. The two mile long unbroken segment of the Book Cliffs escarpment just north of the site is supportive evidence for lack of faulting in the immediate site area. Core from all the deep boreholes were dry when broken open, indicating lack of saturation in the Mancos Shale bedrock. No natural fractures were noted below a depth of 100 feet into bedrock; most fractures were in the top 50 feet of bedrock, representing the weathered Mancos Shale.

Use of the area as a disposal cell would not preclude the recovery of the only resource that has moderate to high potential for development—oil and gas, which could be explored and recovered (if present) by directional drilling.

The landscape at the disposal site is dominated by depositional (aggradational), rather than erosional (degradational), processes. The fluvial-geomorphological features at the site pose little risk for a disposal cell. Sheet wash from the north will be redirected westward and eastward around the disposal cell by the construction of the wedge. The northward advance of headward incision of the West Branch of Kendall Wash will have to be monitored. The incised channel of Crescent Wash shows little historic or future tendency to migrate eastward toward the disposal cell footprint.

3.0 Ground Water Hydrology

3.1 Hydrogeologic Investigation

The hydrogeologic investigation consisted of characterizing the physical and geochemical properties of the hydrogeologic units and documenting water use at the Crescent Junction Disposal Site. Major points are summarized below. Detailed commentary on the hydrogeologic characterization is provided in Attachment 3.

3.2 Identification of Hydrogeologic Units

The Crescent Junction Disposal Site is underlain by alluvial and colluvial material whose thickness is variable, ranging from a trace to nearly 25 feet in places. This material was deposited in shallow swales and washes that were carved into the weathered Mancos Shale. Under current climatic conditions, none of the shallow swales or washes contain ground water.

The alluvial and colluvial materials are underlain by the Mancos Shale, which is approximately 2,400 feet thick below the site and forms an important regional confining unit. The Mancos Shale is composed of calcareous shale, mudstone, and claystone that contains thin sandstone lenses, interbedded siltstone, and zones of limestone concretions and dolomite or limestone beds. These fine-grained rocks have very low permeabilities and inhibit infiltration of precipitation (Hood 1976). The Mancos Shale forms a massive barrier to horizontal and vertical ground water movement (Freethey and Cordy 1991).

Minor quantities of ground water are present in the Mancos Shale at depths that exceed 100 feet. The ground water is very saline to briny with total dissolved solids (TDS) concentrations ranging from 23,000 milligrams per liter (mg/L) at well 0208 to 42,000 mg/L at wells 0201 and 0204. At these TDS concentrations, the State of Utah designates the ground water in the Mancos Shale to be *Class IV-Saline Ground Water* (Utah State Code, R317-6-4, Ground Water Class Protection Levels). Primarily on the basis of its salinity, this ground water is believed to be connate (Freethey 2006, personal communication) and therefore, very old and unconnected to deeper, regional aquifer systems. It also appears to be disconnected from sources of freshwater recharge and acts as a confining layer. The zone of connate water at the Crescent Junction Disposal Site is not considered an aquifer.

The uppermost aquifer beneath the Crescent Junction Site is the Dakota aquifer, which underlies the Mancos Shale confining unit, approximately 2,400 feet below the ground surface. A schematic diagram of the hydrogeologic units that underlie the Crescent Junction Site is presented in Figure 3–1. The Dakota aquifer is composed of the Dakota Sandstone and the Cedar Mountain Formation. Published accounts of drill holes advanced to the Dakota aquifer within a radius of approximately 20 miles of the Crescent Junction Disposal Site indicate that the ground water is mostly salty (Sumsion 1979). Ground water samples from the Dakota aquifer were not obtained as part of this project because of the great depth at which the aquifer occurs.

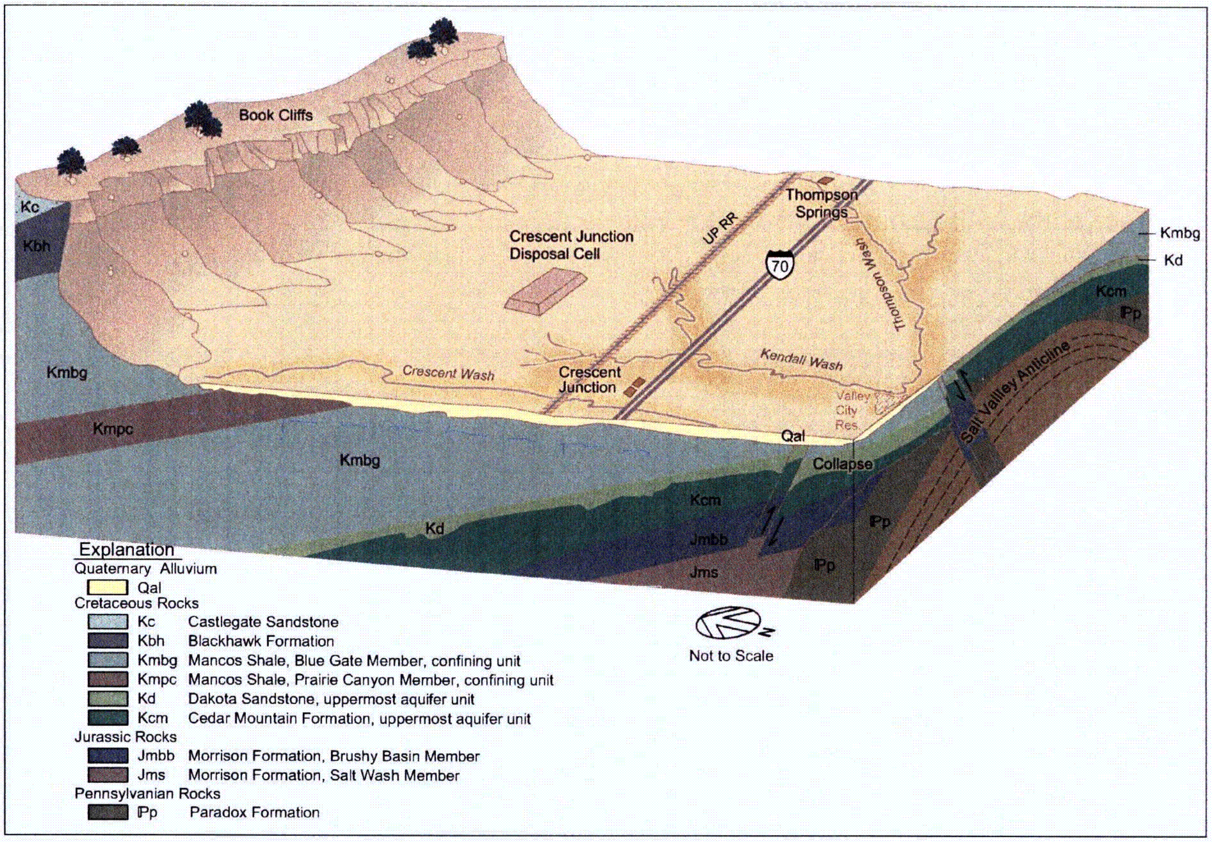


Figure 3–1. Schematic Block Diagram Depicting the Major Hydrogeologic and Topographic Features at the Crescent Junction, Utah, Disposal Site

3.3 Hydraulic and Transport Properties

The Dakota aquifer is recharged by infiltration of runoff and precipitation along the southern flank of the Uinta Mountains, where the aquifer units are exposed. As presented in Figure 3–2, these exposures occur near the town of Vernal, Utah, approximately 100 miles north of the Crescent Junction Disposal Site. From there the ground water in the Dakota aquifer flows in a southerly direction beneath younger hydrogeologic units that comprise the Uinta Basin. The Crescent Junction Disposal Site is located south of the Uinta Basin, where the Cretaceous-age aquifer beds emerge after being buried deeply beneath the Uinta Basin. Sedimentary beds belonging to the Dakota aquifer are exposed at the land surface approximately six miles south of the Crescent Junction Disposal Site, where they are brought to the surface by upwarping caused by the Salt Valley Anticline (Figure 3–2). Ground water discharge from the Dakota aquifer, which could occur as springs or zones of enhanced evapotranspiration along the flanks of the Salt Valley Anticline, was not observed during the field investigation except for one area in Sections 29 and 32, T22S, R21E, approximately 13 miles southeast of the site.

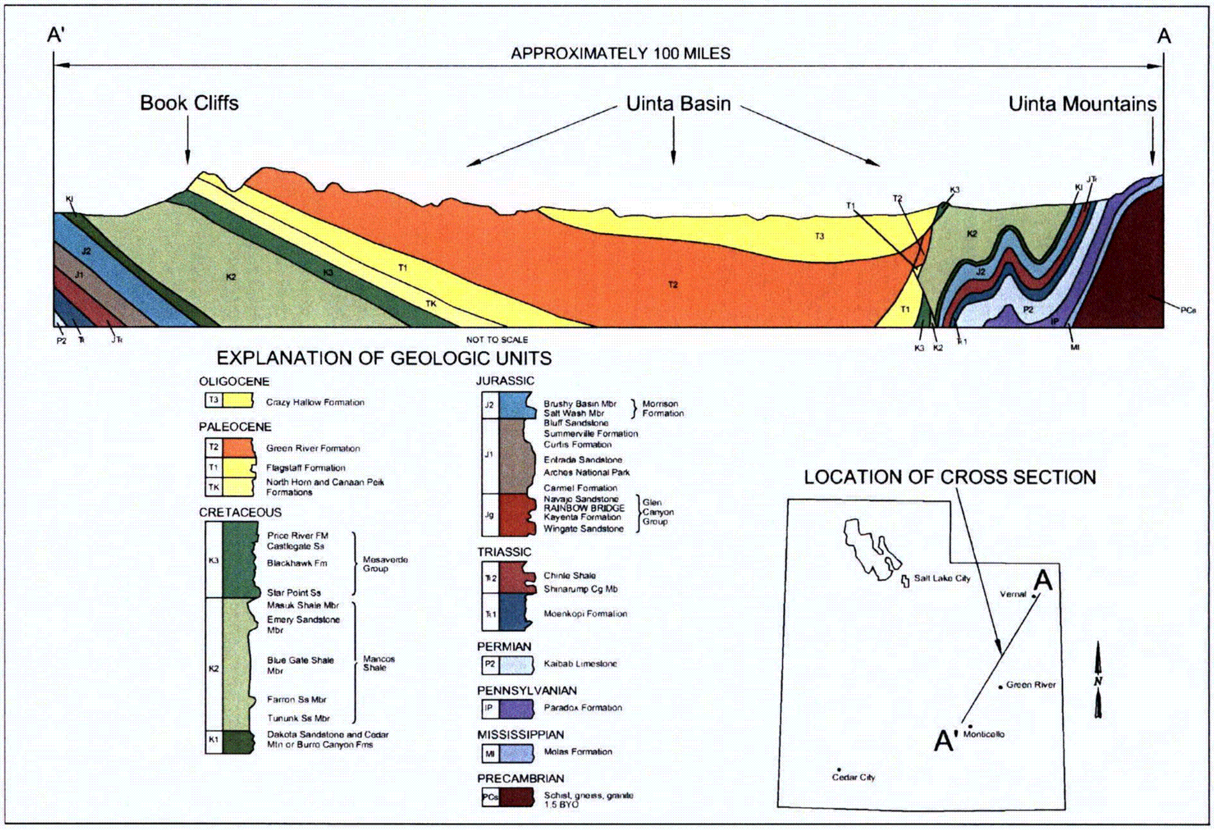


Figure 3–2. Regional Scale Cross Section Depicting Hydrogeologic Elements, Crescent Junction Site, Utah (modified from Hintze et al. 2000)

Hydrologic tests have shown that hydraulic conductivities decrease with increasing depth in the Mancos Shale. Within the weathered zone of the Mancos Shale the horizontal and vertical hydraulic conductivities were found to be approximately 2×10^{-3} centimeter per second (cm/s) and 1×10^{-4} cm/s, respectively. Within the more competent, unweathered Mancos Shale the geometric mean of all measured hydraulic conductivities was approximately 3.5×10^{-8} cm/s. The vertical travel time for ground water to migrate through the Mancos Shale to the Dakota aquifer is conservatively estimated to range from 3,330 to 33,300 years (Attachment 3, Appendix E).

3.4 Geochemical Conditions

The Crescent Junction Disposal Site is located in an area where geochemical processes are likely to attenuate the concentrations of ammonia and uranium (the main constituents of concern in the tailings pile fluids), which might leach from the disposal cell. The chemical retardation of ammonia is anticipated to occur primarily through ion exchange with sodium, potassium, calcium, and magnesium. Most of the ion exchange is projected to involve sodium, which dominates the cation population in the briny connate ground water underlying the site. Uranium is expected to precipitate from solution as it migrates slowly into the deeper recesses of the Mancos Shale. Geochemically reducing conditions are very likely to exist at increasing depth below the surface because of the anoxic conditions imparted by gaseous hydrocarbons and carbonaceous shale. Pockets of natural gas were encountered during the drilling conducted as part of this project. Commercial exploration for oil and gas has been, and continues to be, common in the Crescent Flat area. Based on these conditions, the Mancos Shale beneath the

Crescent Junction Site is expected to naturally attenuate any dissolved chemical species in tailings leachate that would be harmful to human health and the environment. The geochemical attenuation would retard the downward migration of these constituents by a factor of 1 to 3, further increasing vertical travel times to the Dakota aquifer. Details of the geochemical attenuation modeling and the background ground water quality are in Attachment 4, Appendix B, and Attachment 5, Appendix H, respectively.

3.5 Water Use

There are no private or municipal wells within two miles of the Crescent Junction Disposal Site. Figure 3–3 illustrates the occurrence of water resources in the Crescent Junction area.

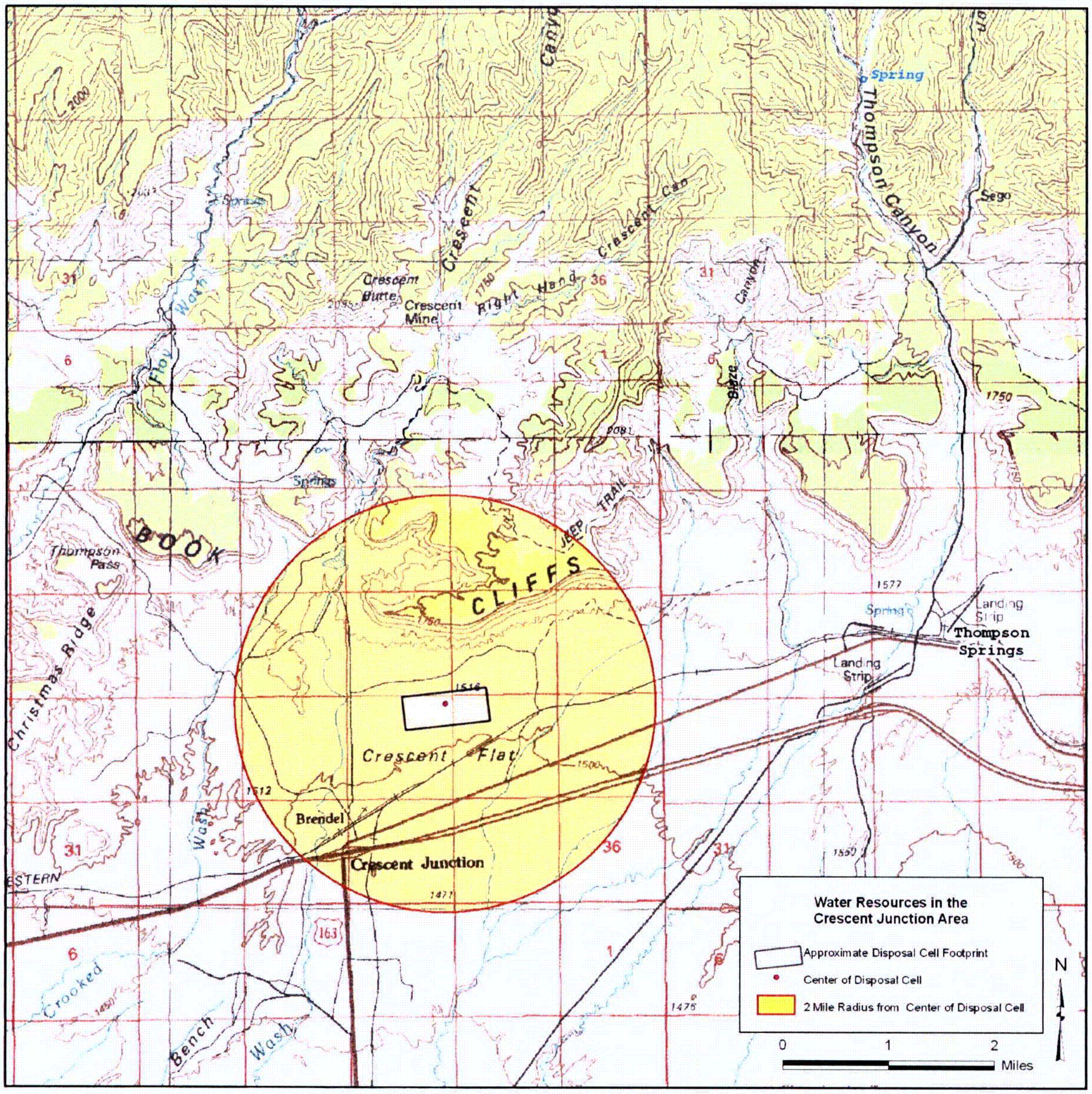


Figure 3–3. Water Resources in the Vicinity of Crescent Junction, Utah

The nearest municipal water supply to the Crescent Junction Disposal Site is in Thompson Canyon, located approximately seven miles north of Thompson Springs, Utah. The springs in this area yield approximately 20 gallons per minute (Sumsion 1979) from a carbonaceous shale layer near the top of the Neslen Formation (Willis 1986), which is a part of the Cretaceous Mesaverde Group. The springs constitute the sole source of potable water in the immediate area. In 2006, DOE installed a new three inch water line, which extends from Thompson Springs and serves residential and commercial customers in the vicinity of the Crescent Junction Disposal Site. A water pipe-line to provide construction water for the disposal cell will be installed prior to cell construction. This non-potable supply is planned to be abandoned following the completion of construction.

End of current text

4.0 Geotechnical Stability

This section and associated reference documents describe the geotechnical engineering aspects of the remedial action. The following aspects of the remedial action are described: the geotechnical information and design details related to the disposal site, the disposal cell and cover, and the properties of the soil materials. Materials described include the foundation and excavation materials and the RRM. Related geological aspects such as geology, geomorphology, and seismic characterization are presented in Section 2.0 of this document.

4.1 Site and Material Characterization

4.1.1 Geotechnical Investigations

Geotechnical investigations were performed at both the Crescent Junction Disposal Site and the Moab Processing Site to define the occurrence and engineering properties of the subsurface materials. Data obtained from these investigations are presented in Attachment 5. Subsurface information was obtained from test pits, boreholes, coreholes, surface geophysical investigations (seismic refraction), and laboratory testing. Each of the test-pit and test-hole locations were continuously observed or logged by a field engineer or geologist.

The subsurface investigation program at the Crescent Junction Disposal Site began in August 2005 with the excavation of two test pits (0151 and 0153) that were advanced through the Quaternary overburden material into the first several feet of the weathered Mancos Shale. The initial test pits were backfilled immediately after they were logged and sampled. Remaining test pits (0152, 0154, and 0156) were excavated and sampled in October and November 2005 and were left open for future inspection by interested stakeholder groups. Logs of the test pits are presented in Attachment 5, Appendix D. Bulk samples collected from the test pits were used to determine material classification, compaction characteristics, hydraulic properties, and strength properties. Results of the geotechnical testing are presented in Attachment 5, Appendixes E and K.

During September through November 2005, the geotechnical investigation of the Crescent Junction Disposal Site continued with the drilling of 100 soil borings within and immediately beyond the conceptual footprint of the disposal cell. These borings were advanced to the depth of practical refusal, which was in the first several feet of weathered Mancos Shale. Drive samples were collected using a Modified California Sampler and a 140-pound hammer falling 30 inches. A registered geologist recorded the blow-count data and made provisional classifications of the soils at the time of drilling. Logs of the geotechnical boreholes are presented in Attachment 5 Appendix B. The soil samples were temporarily stored on site and transported at regular intervals to the geotechnical testing laboratory. Temperature monitoring at the temporary storage area revealed that the samples were not exposed to freezing conditions prior to being transported offsite. Results of the geotechnical testing are presented in Attachment 5, Appendix E.

Between August and December 2005, a total of 10 coreholes (0201 through 0210) were advanced to a depth of 300 feet below the land surface, tapping into the firm, unweathered portions of the Mancos Shale. The coreholes were drilled by advancing conventional soil borings to refusal in the top several feet of weathered bedrock, coring 15 feet beyond the refusal depth and cementing surface casing to that depth, attaching a typical oil-field blow-out preventer to the top of the surface casing, and coring to a depth of 300 feet in the Mancos Shale. Conventional geotechnical soil sampling was performed in the unconsolidated soil zone, and continuous HQ size (3.38 inches) core was obtained from the bedrock. Three additional, shallow coreholes (0211 through 0213) were drilled to a maximum depth of 42 feet into the weathered Mancos Shale for hydrologic testing. Logs of the coreholes are presented in Attachment 5, Appendix A. Under the direction of the site geologist, the rock coring was conducted using an air-water mist to minimize the introduction of foreign fluids into the rock formation. Accumulated fluids, which included formation water in some coreholes, were periodically air lifted out of the advancing hole. Natural gas was detected in several of the coreholes as they were being drilled; however, highly pressurized gas pockets were not encountered at the site. Samples from the coreholes were analyzed for geochemical characteristics (i.e., soluble mineral species, x-ray-diffraction, distribution coefficients, and sequential batch leaching) and these results were developed into a reactive transport model (Attachment 4, Appendix B). Borehole geophysical logs, which included optical and acoustical televiewer, caliper measurements, compensated density, neutron logs, induction resistivity, natural gamma, and rock quality designation, are found in Attachment 5, Appendix C.

In October and November 2005, seismic refraction was used to characterize the rippability of the subsurface materials at the Crescent Junction Site. Orthogonal seismic refraction lines were established at coreholes 0202, 0204, 0206, 0207, and 0208. Each seismic line was 500 feet long and geophones were spaced at approximately 10 foot intervals. Three velocity zones were identified in the subsurface: (1) alluvial overburden with an attendant shear wave velocity of approximately 1,200 to 1,300 ft/s, (2) weathered Mancos Shale with an attendant shear wave velocity of approximately 4,100 to 5,200 ft/s, and (3) competent Mancos Shale with a shear wave velocity of approximately 9,000 to 10,000 ft/s. Based on the seismic shear wave velocity, the weathered Mancos Shale is considered rippable with a dozer with at least 300 horsepower (D8) with 50,000 pounds pry out force on a single point ripper. Details of the seismic refraction analysis are presented in Attachment 5, Appendix G. In October 2007, three test pits were excavated with a tracked excavator to confirm shale rippability. The Mancos Shale was found to be rippable with an excavator cutting in one direction to the depth of the proposed disposal cell floor.

During August 2005 through December 2005, geotechnical borings, test pits, and cone penetrometer test (CPT) soundings were advanced into the tailings pile material at the Moab Processing Site. A total of 24 boreholes (0700 to 0723) were advanced to a maximum depth of 96.5 feet below the surface; twelve test pits (0621 to 0632) were dug to a depth of 20 feet below the surface; and 15 CPT soundings with pore-pressure dissipation tests (0381 through 0395) were advanced to a maximum depth of 81.9 feet below the surface. Logs of the geotechnical borings and test pits are presented in Attachment 5, Appendix I. Results from the cone penetration tests are presented in Attachment 5, Appendix F. Soil samples from the tailings characterization were classified for index properties, hydraulic properties, and strength properties. Results of the geotechnical tests are presented in Attachment 5, Appendixes J and N. These results were used to develop preliminary materials-handling recommendations, and to ascertain the volume and weight of the tailings (Attachment 1, Appendixes I and J).

4.1.2 Disposal Site Stratigraphy

Unconsolidated Quaternary material that reaches a maximum thickness of approximately 23 feet covers most of the disposal site. These deposits cover Mancos Shale bedrock, which has a thickness of approximately 2,400 feet beneath the center of the disposal cell.

The Quaternary deposits are typically 10 feet to 12 feet thick and consist mainly of alluvial mud and lesser amounts of eolian material and coarse deposits in a few swales. Alluvial mud deposited by sheet wash is mostly silt and clayey silt, and highly calcareous. Eolian material is mostly sandy silt that occurs in thin, discontinuous layers in the lower part of the alluvial mud deposits. Coarse material that consists of sand, gravel, and small boulders occurs in a few places at the base of the alluvial mud where channels or swales have been cut as deep as 20 feet into Mancos Shale bedrock.

The Mancos Shale consists of the Blue Gate Member in the south part of the site overlain by the Prairie Canyon Member in the north part of the site. The Blue Gate Member consists mostly of mudstone, and the Prairie Canyon Member contains some layers of very fine-grained sandstone and siltstone in addition to the mudstone. The top 50 feet of Mancos Shale bedrock is weathered; the top 10 to 30 feet is most weathered and contains abundant natural fractures that are typically coated or filled with gypsum (and some calcite). Fractures are rare below a depth of 50 feet into the Mancos Shale and are absent below a depth of 100 feet into bedrock.

Materials that will be used in construction of the disposal cell cover (including the radon barrier) will be obtained from the disposal cell excavation. Modeling using data collected from samples of weathered Mancos Shale indicates that these materials will meet the cover design criteria required by the TAD (DOE 1989).

The disposal cell floor elevation was determined will be excavated a minimum of two feet into the weathered and fractured Mancos Shale. As described in Section 3.3, the weathered and fractured Mancos Shale has hydraulic conductivities of 10^{-4} to 10^{-3} cm/s. The cover system constructed on the disposal cell will have hydraulic conductivities significantly lower than the subsoil values, thereby meeting the requirements of 40 CFR 264.228 to prevent "bathtubbing".

4.2 Geotechnical Engineering Evaluation

This section and referenced supporting documents present the geotechnical engineering evaluation of the information and analyses that have been undertaken to demonstrate that the remedial action will meet relevant EPA standards for long-term disposal cell stability. Information and analyses that have been performed include slope stability, settlement and cover cracking, and liquefaction analyses. Specific calculation sets that discuss information and present numerical analyses are listed in and included in Addendum D. Analyses are performed for design-basis events such as the design earthquake (Attachment 2, Appendix F), the design flood arising from the Probable Maximum Precipitation (PMP) (Attachment 1, Appendix E), and extreme meteorological conditions.

4.2.1 Slope Stability

The proposed disposal cell will be partially below and partially above the existing ground surface. A clean fill embankment will be constructed around the perimeter of the disposal cell to form the sides of the above ground section of the disposal cell. A multi-layer cover, eight feet thick, will be placed over the RRM and will extend over the perimeter embankments. The stability of the perimeter embankments and the UMTRA cover is important for maintaining long-term containment.

The slope stability analyses are presented in Addendum D, Calculation C-10. These analyses show that for both static and dynamic conditions, the cell foundation, the slopes of the disposal cell, and the cover system will not fail or otherwise adversely affect the disposal cell. The most critical slope section was analyzed for both short-term (end-of-construction) and long-term conditions. The following is a brief description of the work done to support these conclusions.

Material Properties

Material properties (Table 4–1) used in the stability analysis were obtained from borings, laboratory test results, and previous analyses. No ground water table is present at Crescent Junction and none was included in the analysis.

Table 4–1. Material Properties Used in Stability Analysis

Material	Unit Weight			Shear Strength			
				Total		Effective	
	Dry (pcf)	Moisture Content (%)	Moisture (pcf)	Friction Angle (degree)	Cohesion (psf)	Friction Angle (degree)	Cohesion (psf)
UMTRA Cover	111	11.7	124	26	0	26	0
Tailings	98	17.4	115	0	615	32	0
Dike Fill	111	17.4	124	19	0	26	0
In-situ Overburden Material-ML	92	6.7	98	26	0	26	0
Weathered Mancos Shale	104	7.3	112	25	0	25	0

Critical Slope Geometry

A section of the disposal cell south embankment with the greatest height along the perimeter embankment represents the critical slope, and has the following slope geometry:

- Existing ground surface slopes from north to south.
- Ground surface elevation: inside the cell (north) = 4,954 feet.
- Ground surface elevation: outside the cell (south) = 4,944 feet.
- Top of embankment elevation: 4,964 feet.
- Cover material eight feet thick with top elevation: 4,972 feet.
- Water surface was not used.

- Embankment exterior slope was configured at 5:1.

Method of Analysis

The analysis was performed with computer program SLIDE, Version 5.0, by Rocscience. The SLIDE program analyzes the slope with multiple methods to determine factor of safety, including Bishop Simplified, Janbu Simplified, Janbu Corrected, Spencer, Morgenstern-Price, and Corps of Engineers Methods. Bishop and Janbu methods employ limit equilibrium analysis method, Spencer and Morgenstern-Price methods use both force equilibrium and moment equilibrium to determine safety factors. In this analysis, Spencer results yielded the lowest factor of safety.

The analysis was performed for the end-of-construction (short-term) and long-term cases. Stability of the disposal cell perimeter embankment and cover system was also assessed for the design seismic event for both the short-term and long-term cases. Seismic conditions were analyzed using guidance provided in the TAD (DOE 1989). The TAD requires the use of pseudo-static approach where peak horizontal ground acceleration (PHA) value of 0.22 g (previously determined) is taken as half of PHA or 0.11 g for end-of-construction case, and two-thirds of PHA or 0.15 g for long-term case.

Results of Analysis

The analysis results, summarized in Table 4–2, indicate that the safety factor of the critical slope exceeds the safety factor required by the TAD for all of the cases. The stability results indicate that the proposed disposal cell site, perimeter embankments, and cover system will be stable when constructed of on-site materials and with the planned embankment geometry.

Table 4–2. Summary of Slope Stability Analysis

Loading Condition	Calculated Factor of Safety	Factor of Safety Required by TAD
End-of-construction:		
Static	1.82	1.3
Pseudostatic (k_h = 0.11 g)	1.17	1.0
Long-term:		
Static	2.35	1.5
Pseudostatic (k_h = 0.15 g)	1.33	1.0

K_h = pseudostatic coefficient

4.2.2 Settlement

Evaluation of tailings settlement in the disposal cell is presented in Addendum D, Calculation C-11. The evaluation was based on geotechnical test results on tailings sampled by Shaw E&I Inc., 2006, and Golder Associates, Inc., 2006. Consolidation characteristics were determined for remolded samples of sand tailings, transition tailings, and slimes tailings. Primary and secondary settlements are estimated based on compression of the tailings under their own weight and by each subsequent tailings layer and by the cover material.

The magnitude of primary and secondary settlement was calculated based on the consolidation tests and on the following inputs and assumptions:

- All natural overburden will be removed, and the excavation for the disposal cell will extend to a minimum of two feet into the Mancos Shale. Settlement of the foundation soil will therefore be negligible.
- RRM will be placed, spread, and compacted in layers or until all RRM has been moved. Settlement of the RRM will be due largely to settlement of material under its own weight and ultimately due to the additional weight of the protective cover.
- RRM will be mixed and dried to near optimum moisture content prior to transport to the Crescent Junction Site. Once there, RRM will be placed in layers per specifications and compacted to 90 percent of the maximum density per American Society for Testing and Materials (ASTM) D698.
- RRM thickness assumed to be 38 feet and cover thickness assumed to be 10 feet.
- Consolidation properties of newly placed RRM (Cc – Compression Index or Coefficient of Consolidation, e_0 – initial void ratio) will be similar to the ones obtained for this analysis by averaging values for the sand tailings, transition tailings, and slimes.

Table 4–3 contains test results from consolidation testing of tailings material from the Moab Site. Table 4–4 contains a complete summary of geotechnical properties for the tailings material tested.

Table 4–3. Consolidation Test Data

Sample No.	Soil Type	Coefficient of Consolidation (Cc)	Initial Void Ratio (e_0)
GABT -04	Sand tailings	0.15	0.880
GABT -06	Sand tailings	0.07	0.638
GABT -09	Transition tailings	0.20	0.808
GABT -10	Transition tailings	0.17	0.703
GABT -11	Slime tailings	0.38	1.157
GABT -13	Slime tailings	0.34	1.052

For the settlement calculations, e_0 of 0.87 and a Cc of 0.16 were used. The e_0 was determined by averaging the void ratios of the different types of tailings material – sand, transition, and slimes. The compression index was selected based on the anticipated behavior of the combined sand, transition, and slimes material dried to near optimum moisture content for compaction. The combined material will behave more like the sands and transition material than a straight numerical average would indicate.

The results of the settlement analyses indicate that primary settlement of the tailings will be 11 inches and secondary settlement will be approximately six inches. For the total height of the tailings and cover, the magnitude of total settlement is insignificant. Also, because of the granular composition of the tailings, most of the primary settlement will take place rapidly.

Table 4–4. Geotechnical Properties of Moab Tailings Pile Material

Bench Test Sample No.	Soil Type	Atterberg Limits (LL/PL/PI) ASTM D4318	Sieve/Hydrometer Analysis % Gravel	% Sand	% Silt	% Clay	Sample Prep Dry Unit Weight (pcf) / Water Content (%) / Confining Pressure (psi)	Hydraulic Conduc-tivity (1) (c/s)	Triaxial Shear Strength (2) C psf	Effective Friction Angle (degrees)	Coefficient of Consoli-dation (Cc)	Volume Moisture Content at 15-bar (3)	Maximum Dry Density (pcf) (4)	Optimum Moisture Content (%) (4)	Settled Compaction (%) (4)
GABT-01	Cover Soil	NP	4	73	18	5	106.3/7.0/2.5 106.3/7.0/2.5 106.3/7.0/2.5	4.7E-06 7.6E-06 1.1E-06					117.7	11.9	82.0
GABT-02	Cover Soil	NP	3	80	14	3							109.2	13.8	85.8
GABT-03	Sand Tailings	NP	1	83	15	2	90.5/14.4/2.25 90.5/14.4/2.25 90.5/14.4/2.25	2.7E-04 3.8E-04 7.9E-06	0	34.5			106.3	12.7	79.3
GABT-04	Sand Tailings	NP	0	76	21	3	88.2/17.5/2.25 88.2/17.5/2.25 88.2/17.5/2.25	1.7E-04 1.3E-05 1.8E-05	0	36.5	0.15	6.1	103.9	15.6	82.2
GABT-05	Sand Tailings	NP	3	76	17	5	101.7/15.3/2.25 101.7/15.3/2.25 101.7/15.3/2.25	3.1E-04 2.2E-04 2.1E-04	0	38.3			113.3	13.1	90.9
GABT-06	Sand Tailings	NP	1	83	13	4					0.07	24.4	107.3	14.6	82.6
GABT-07	Transition Tailings	31/22/9	1	49	42	8	96.3/20.5/2.5 96.3/20.5/2.5 96.3/20.5/2.5	1.2E-05 1.4E-05 1.3E-05	0	47.2			107.3	18.4	78.8
GABT-08	Sand Tailings	NP	7	72	19	9	101.4/17.9/2.25 101.4/17.9/2.25 101.4/17.9/2.25	3.2E-05 2.1E-05 7.4E-05	0	37.1			112.8	16.0	83.3
GABT-09	Transition Tailings	23/20/3	0	42	50	8	91.8/23.0/2.5 91.8/23.0/2.5 91.8/23.0/2.5	6.4E-05 6.9E-05 7.1E-05	0	36.3	0.20	24.4	102.0	21.1	87.9
GABT-10	Transition Tailings	19/17/2	0	70	24	6					0.17	>50.5	107.8	18.7	94.6
GABT-11	Slimes Tailings	56/27/29	0	22	53	25					0.38	27.6	96.0	27.8	68.5
GABT-12	Slimes Tailings	35/19/16	0	41	47	12	83.6/20.9/2.5 83.6/20.9/2.5 83.6/20.9/2.5	8.4E-05 2.1E-05 1.9E-05	0	50.8			101.6	22.5	39.3
GABT-13	Slimes Tailings	49/23/23	0	12	63	25					0.34	25.1	95.0	28.7	84.9
GABT-14	Slimes Tailings	43/22/21	0	16	62	22	81.2/22.8/3.0 81.2/22.8/3.0 81.2/22.8/3.0	2.7E-06 1.8E-06 1.8E-06	0	37.6			101.5	20.9	76.6

LL/PL/PI – liquid limit, plastic limit, plasticity index.

(1) Hydraulic conductivity tests performed at low confining pressures.
(2) Triaxial shear strength tests performed at low confining pressures.
(3) Capillary-moisture relationships analyzed with WP4 potentiometer.
(4) Test results from GAI 2006.

4.2.3 Liquefaction Potential

Evaluation of tailings liquefaction potential in the disposal cell is presented in Addendum D, Calculation C-12. For liquefaction to occur, the tailings material in the disposal cell would have to be relatively loose under saturated conditions. The evaluation was performed in the unlikely event that the tailings become saturated.

Although the tailings will be placed in the disposal cell in a compacted and unsaturated condition, downward migration of water may create saturated zones within the tailings. The potential liquefaction of saturated zones of the tailings was checked with standard procedures outlined in Day (1999). The Mancos Shale underlying the tailings disposal site is not considered to be liquefiable.

The evaluation of tailings liquefaction potential is performed using Seed-Idriss Simpified Procedure based on Standard Penetration Test and modified per the 1996 National Center for Earthquake Engineering Research (NCEER) and 1998 NCEER/National Science Foundation (NSF) Workshops on Evaluation of Liquefaction Resistance of Soils. Calculation of liquefaction potential involves comparison of the seismic cyclic stress ratio that would cause liquefaction with the cyclic resistance ratio for tailings at a specific depth of analysis. The factor of safety against liquefaction in a tailings layer is calculated by dividing the shear stress required to cause liquefaction in the layer by the shear stress generated in that layer by the design earthquake.

For the calculation, the following assumptions and inputs were made.

Assumptions:

- Existing tailings at the Moab Site will be dried to optimum moisture content prior to transport to the Crescent Junction Disposal Site. Once there, tailings will be placed in layers per specification and compacted to a minimum of 90 percent relative compaction. In general, tailings material should not be saturated.
- For analysis purposes only, tailing were assumed saturated at full height (worst case).
- Seismic design input as given in the TAD and RAP Attachment 1, Appendix D, for estimated peak acceleration at the ground surface for Crescent Junction.
- Liquefaction potential will be analyzed using earthquake moment magnitude of 6.5 (Addendum D, Calculation C-12).
- Standard Penetration Test (SPT) blow counts can be reasonably estimated for the placed and compacted materials based on assumed relative density of the compacted tailings layers.

Inputs:

- Assumed tailings thickness: 38 feet (saturated soil thickness: 38 feet)
- Assumed cover thickness: 10 feet
- Peak acceleration at ground surface: 0.22 g (TAD allows 0.11 g at end of construction and 0.15 g for long-term conditions)
- Earthquake moment magnitude: 6.5

The evaluation of liquefaction potential was performed for two cases, tailings with 17 percent fines and tailings with 46 percent fines. The results of the analyses indicate that liquefaction of the tailings will not occur under the assumed soil and seismic conditions. Furthermore, it is considered likely that field SPT N-counts in 90 percent relative density material may result in higher blow counts than assumed in this liquefaction analysis. The TAD indicates the minimum factor of safety considered acceptable for UMTRA sites is 1.5. The calculated factors of safety ranged from 1.37 to 1.84 for the tailings containing 17 percent fines, and from 1.74 to 2.34 for the tailings with 46 percent fines. Due to the extreme (and unlikely) assumption made for saturated conditions to be present at full height of the tailings, it is concluded that the tailings when placed, compacted, and covered in the disposal cell will not be liquefiable.

4.2.4 Cover Cracking

RRM that will be placed at the Crescent Junction Disposal Site is to be stabilized and contained by placement in an encapsulated disposal cell. The cover of the disposal cell serves to prevent the escape of radon from the RRM, as well as to inhibit infiltration of precipitation. Cracking of the disposal cell cover can adversely impact the ability of the cover to achieve those two purposes. Cover cracking was evaluated by comparing the allowable strain of the cover materials with the maximum calculated strain due to differential settlement in the cover (Addendum D, Calculation C-15).

Settlement analyses determined that the settlement of the RRM will be 17 inches or 1.42 feet, occurring at a location with a tailings depth of 38 feet. The settlement of the tailings at the top of the perimeter embankment will be 0 inches where the thickness of tailings tapers to 0 feet. The horizontal distance between the location of maximum settlement and zero settlement is 96 feet. Therefore, the total strain equals 1.42 feet / 96 feet = 0.015 percent strain. For clayey soils, the maximum tensile strain at failure equals 0.065 percent (Gilbert and Murphy 1987). The actual strain, 0.015 percent is much less than the allowable strain of 0.056 percent, thus the cover is not anticipated to crack.

End of current text

5.0 Radon Attenuation

5.1 Cover Design

The remedial action at the Moab Processing Site and the placement of RRM at the Crescent Junction Disposal Site is summarized in Section 1.1.3. The cover design is shown in Figure 5-1. This is the typical UMTRA Project cover using a compacted clay radon barrier to control the rate of radon emission from the cell. The design includes a minimum one-foot-thick interim cover placed directly on the RRM surface as a best management practice to control wind transport of fine material and to provide for a relatively clean, uniform work surface upon which to construct the radon barrier.

The UMTRA Project cover design consists of an interim cover constructed of clean native alluvial materials to a minimum thickness of one foot, a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale, a 0.5-foot-thick infiltration and biointrusion barrier consisting of sandy gravel, and a 3.5-foot-thick frost protection layer that includes the 0.5-foot-thick rock mulch erosion protection layer. The thickness of the radon barrier depends on the thickness of the interim cover, since both layers reduce the rate of radon emission. The thickness of the required radon barrier for the Crescent Junction disposal cell is four feet for a one-foot-thick interim cover.

The radon barrier layer thickness was selected for reduction of radon gas flux to rates below 20 picoCuries per square meter per second ($pCi/m^2/s$). The erosion protection, frost protection, and drain layers were not considered in the calculation of the radon barrier thickness, due to the high permeability of these materials. The side slopes will be constructed of clean fill materials and will be much thicker than the required cover and, therefore, will be adequate to meet the EPA standard for radon flux. Consequently, the side slopes have been evaluated solely for erosion protection. The covers for the side slopes are described in Section 6.4.1.

5.2 Radon/Infiltration Barrier Parameters

The radon barrier design parameters and supporting calculations were used in conjunction with the RADON model (NRC 1989b) to determine the cover thickness necessary to meet the EPA radon flux standard of 20 $pCi/m^2/s$. Guidance provided in the TAD (DOE 1989) was considered in developing the cover design. As with previous UMTRA Project Title I cover designs, the attenuation of radon by the frost protection, drainage, biointrusion, or erosion protection layers is not considered in the baseline analyses, though these layers will further reduce the radon flux rate at the disposal cell surface.

Specific design parameters include long-term moisture content, radon diffusion, radon emanation, density, porosity, layer thickness, average radium-226 activity, and ambient radon concentration. Addendum D, Calculation C-05 presents the input parameters used for each model run as well as the model run results.

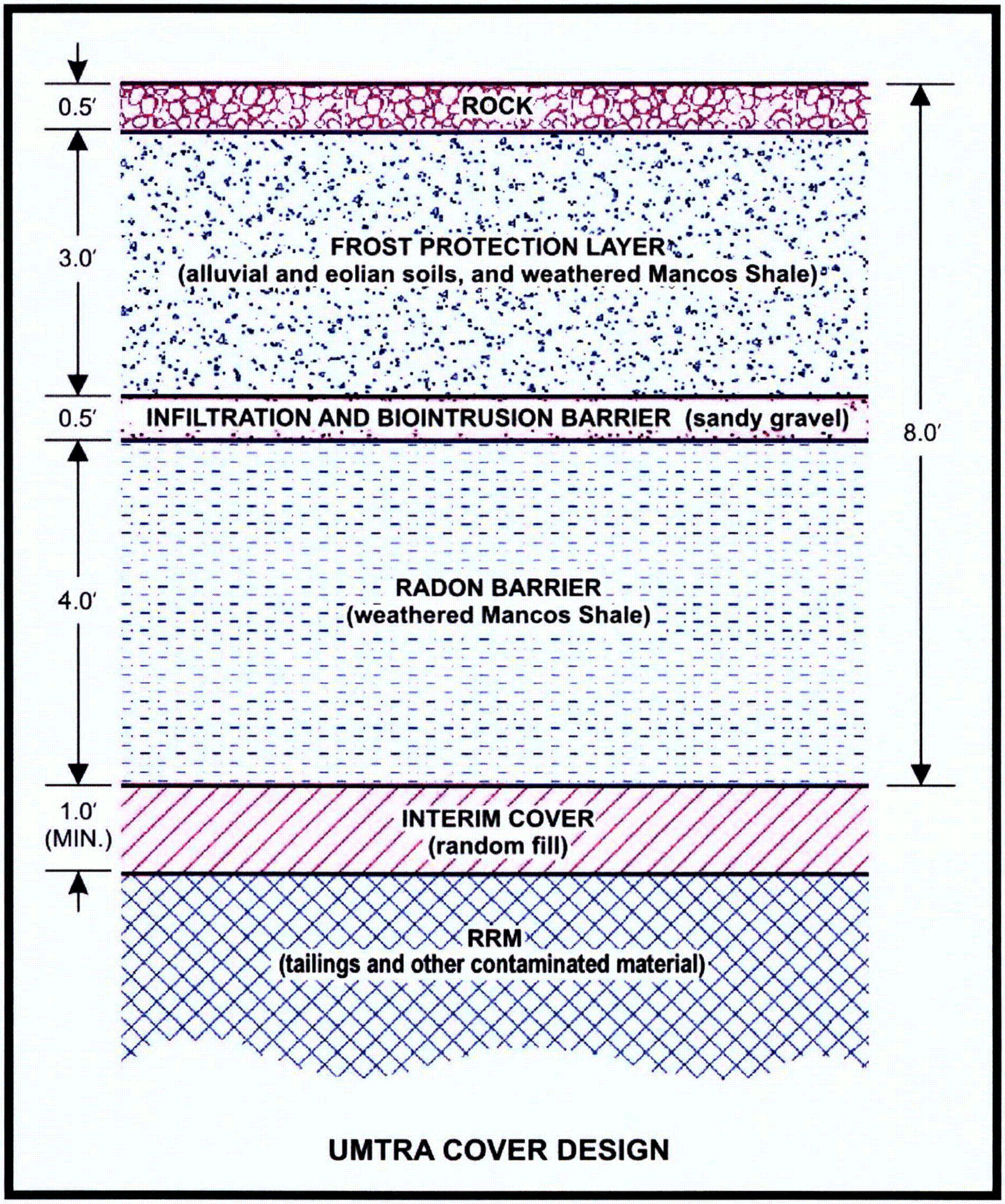


Figure 5–1. Disposal Cell Cover Design

5.2.1 Long-Term Moisture Content

The mean long-term moisture content of the tailings has been modeled as 15 percent, which is in the typical range for tailings.

The mean long-term moisture content of the interim cover is modeled as nine percent. This value is based on the mean of 20 measured 15-bar moisture content analyses as determined by ASTM Method D3152 and presented in Addendum D, Calculation C-05. This mean measured value was evaluated for reasonableness using the Rawls and Brakenseik equation as presented in the NRC Regulatory Guide 3.64 (NRC 1989b) and described in the TAD (DOE 1989). The calculated value using the Rawls and Brakenseik equation is 7.5 percent (DOE 2007b), which agrees well with the measured value of site-specific soils of nine percent.

The mean long-term moisture content of the compacted clay derived from the on-site weathered Mancos Shale is modeled as 12 percent. This value is based on the mean of 12 measured 15-bar moisture content analyses as determined by ASTM Method D3152 and presented in Attachment 5, Appendix E, and Addendum D, Calculation C-05. This mean measured value was also evaluated for reasonableness using the Rawls and Brakenseik equation (DOE 2007b). The calculated value is 12.4 percent, which agrees well with the measured value of site-specific soils of 12 percent. In-situ moisture content for weathered Mancos Shale was not included in the calculation of the mean because in-situ moisture content is not representative of remolded, weathered Mancos Shale. Long-term moisture content of the remolded, weathered Mancos Shale is better represented by the calculated and measured 15-bar moisture content test, due to the difference in material fabric between as-placed cover and the in-place native material.

5.2.2 Radon Diffusion

The radon diffusion coefficient used in the RADON model (NRC 1989b) can either be calculated within the model (based on an empirical relationship with degree of saturation and porosity) or input directly into the model using values measured from laboratory testing. The radon diffusion equations in the 1989 version of RADON are not consistent with a later equation based on a much larger set of data correlating radon diffusion with soil cover materials. Therefore, the RADON code was modified to implement layer-specific radon diffusion coefficients based on the most current relationship using equation 9 from Rogers and Nielson (1991). The code was also modified to direct output to a user specified file instead of a printer.

For the tailings, the calculated radon diffusion coefficient was 0.01037 centimeter squared per second (cm^2/s), for a moisture content of 15 percent by weight and a porosity of 0.44. For the interim cover, the calculated radon diffusion coefficient of 0.01636 cm^2/s was applied based on a moisture content of nine percent and a porosity of 0.38. The radon diffusion coefficient for the UMTRA Project cover compacted clay radon barrier was calculated to be 0.004636 cm^2/s based on the long-term moisture content of 12 percent and a porosity of 0.33.

5.2.3 Radon Emanation

A radon-emanation coefficient of 0.35 was used for all of the tailings, random fill, and cover materials. This is the conservative default value used in the RADON model (NRC 1989b). This value agrees well with the value used for other UMTRA Project sites (e.g., the Grand Junction Disposal Site in Colorado used a radon-emanation coefficient of 0.36).

5.2.4 Dry Densities and Porosities

The dry densities, specific gravities, and porosities were determined from standard compaction tests. The as-placed tailings density was based on compaction to 90 percent of average standard Proctor density. Interim cover and freeze/thaw protection layer materials are all the same material and were based on compaction to 90 percent of the average standard Proctor density. The UMTRA Project cover compacted clay barrier (remolded Mancos Shale) was based on compaction to 95 percent of standard Proctor density.

The porosities of these materials as placed were calculated based on the dry density and the specific gravity of the actual materials. A tailings average specific gravity of 2.8 (based on five samples) was used to calculate an average tailings porosity of 0.44. An average specific gravity of 2.67 (based on seven samples) for site alluvial materials was used to calculate an average porosity of 0.38 for the interim cover. An average specific gravity of 2.65 (based on two samples of on-site weathered Mancos Shale) was used to calculate an average porosity of 0.33 for the compacted clay radon barrier of the UMTRA Project cover.

5.2.5 Layer Thickness

The layers and material sequences are illustrated in Figure 5–1 and represent the geometries of the tailings and of each cover-layer component. Clean fill embankments made of native materials will be used around the perimeter of the disposal cell constructed with 5:1 (horizontal:vertical) exterior side slopes and a minimum 30-foot-wide crest. Because the tailings side slope thicknesses will be far in excess of the cover requirements and with properties comparable to the interim cover material, radon flux through the side slopes was not modeled. A model run with only a RRM layer and a layer of interim cover material did, however, indicate that a side slope thickness of 11 feet would be sufficient to limit the radon flux rate to less than 20 $pCi/m^2/s$. Information on layer thicknesses is in Attachment 1, Appendix B, and Addendum D, Calculation C-05.

For all model runs, RRM thickness of 1310.7 centimeters (cm) (43 ft) is used. This is the maximum thickness of the RRM in the design of the disposal cell. The tailings consist of two layers, a lower layer that is 1,097.3 cm (36 ft) thick and an upper layer that is 213.4 cm (seve feet) thick. This configuration was chosen to allow higher activity waste to be placed in the lower layer providing that the radium activity of the RRM in the upper layer is 707 picoCuries per gram (pCi/g) or less.

The UMTRA Project cover design evaluated for radon flux consists of a one-foot-thick interim cover constructed of uncontaminated native alluvial materials and a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale. The drainage and biointrusion layer, frost protection layer, and rock mulch erosion protection layer are not considered in the modeling.

5.2.6 Radium-226 Activity

Radium-226 activities for the tailings pile materials were assessed (by gamma spectroscopy) on 104 samples of tailings sands, slimes, transitional tailings, and other contaminated materials. The estimated volumes of tailings material are provided in Attachment 1, Appendix K, and

Addendum D, Calculation C-05. The average radium-226 activity of these 104 samples is 707 pCi/g. The number of samples per unit volume of slimes was greater than for the other materials to be placed in the disposal cell. Because the average radium activity of the samples collected from the slimes (1,349.3 pCi/g) is greater than for any of the other materials, this simple average overestimates the radium activity of RRM that will be well mixed before being placed in the cell. Accounting for the volumes and the radium activities of the different materials, the radium activity of completely mixed contaminated material from the Moab Site would be 565 pCi/g.

As the RRM is placed in the lower layer of the cell, the radium activity will be monitored only occasionally. As the RRM is placed in the upper layer (seven feet) the radium activity will be carefully monitored to ensure that the radium activity in the upper seven feet does not exceed 707 pCi/g. In modeling the rate of radon emission from the top of the radon barrier, the radium activity of the lower layer has been set equal to the average of the slimes (1,349.3 pCi/g) and the upper layer to the average of all samples (707 pCi/g). This is a conservative approach as the overall volume-weighted average radium activity is 565 pCi/g and the modeled volume-weighted average is 1,245 pCi/g.

The radium-226 activity of the alluvial materials to be used for the interim cover and the clean fill perimeter dikes is based on five samples of native materials collected from the Crescent Junction Site. The radium-226 activity of the alluvial material ranged from 1.4 to 2.3 pCi/g, with a mean value of 1.9 pCi/g.

The radium-226 activity value for the compacted clay layer is based on two samples of Mancos Shale collected from the Crescent Junction Site that will be used to construct the compacted clay radon barrier and clean-fill perimeter dikes. The radium-226 activity of the weathered Mancos Shale ranged from 1.6 to 3.0 pCi/g, with a mean value of 2.3 pCi/g.

5.2.7 Ambient Radon Concentration

The RADON default ambient radon activity in air of 0 picoCuries per liter (pCi/L) was used for the RADON model (NRC 1989a) because it has little influence on the model. Activities of air samples collected at background locations have a range of 0.5 to 1.2 pCi/L.

5.3 Evaluation of the Radon Barrier

This section summarizes the manner in which the input parameters presented above were evaluated to develop a radon barrier design that will comply with the EPA radon flux standard of 20 pCi/m^2/s using parameters as discussed in Section 5.1 as input for the RADON model (NRC 1989a). Several runs of the RADON model were performed to determine the minimum required radon barrier for radium activities corresponding to the raw average and the volume-weighted average of the RRM. The RADON model runs are summarized in Addendum D, Calculation C-05.

Three model runs for the UMTRA Project cover design were performed to assess model sensitivity to certain variables as described below.

- Model run UMTRA 1a uses mean input values for the UMTRA Project style cover with a one-foot-thick interim cover. The RRM is placed in a single layer 43 feet thick with a radium activity of 707 pCi/g. The thickness of the radon barrier layer is optimized to limit the radon flux rate to 20 $pCi/m^2/s$.

- Model run UMTRA 1b is identical to UMTRA 1a except that the radium activity of the RRM is set equal to the volume-weighted average of 565 pCi/g.
- Model run UMTRA 1c the RRM is divided into two layers. The lower layer is 36 feet thick with a radium activity of 1,349.3 pCi/g and the upper layer is seven feet thick with a radium activity of 707 pCi/g. The radon barrier layer is four feet thick and the model is run to predict the rate of radon flux through the barrier layer.

Modeling results indicate that for UMTRA 1a, a radon barrier thickness of 3.9 feet is required, for UMTRA 1b, the optimized barrier thickness is 3.6 feet and for UMTRA 1c, the radon flux through the radon barrier layer would be 19.9 $pCi/m^2/sec$.

The final cover design will be based on actual measurements of the as-placed contaminated materials and will demonstrate compliance with the radon flux standard.

5.4 Summary and Conclusions

The disposal cell and radon barrier design (four feet thick) will control radon flux to levels below EPA standards stated in 40 CFR 192.02(b). DOE has committed to stabilizing the RRM for long-term control in accordance with EPA standards, NRC guidelines, and UMTRA Project health and safety requirements.

The radium activity of the upper seven feet of waste will be closely monitored as it is placed to ensure that the final radon barrier thickness will limit long-term radon flux through the barrier layer to 20 $pCi/m^2/sec$. If the results of this monitoring indicate the need, the higher activity material will either be mixed with lower activity material or placed in a lower segment of the cell still under construction. In a worst-case scenerio, the thickness of the radon barrier layer will be adjusted to ensure compliance with 40 CFR 192.02(b).

6.0 Surface Water Hydrology and Erosion Protection

6.1 Hydrologic Description of Current Conditions

The Crescent Junction Disposal Site is located on a low-gradient, south-facing slope known as Crescent Flat. The Book Cliffs lie to the north of the disposal site. The average grade of Crescent Flat is approximately 1.4 percent, sloping southward down from the base of the Book Cliffs. There are four major drainage basins in and adjacent to the disposal site that are defined based on four ephemeral streams in the area: East and West Branches of Kendall Wash, which join immediately upstream of I-70; Crescent Wash, located west of the disposal cell site; and Blaze Wash, located east of the cell site. All four washes ultimately drain into the Green River 25 miles south to southwest of the disposal cell site. The major basins associated with these washes are shown on Figure 6–1.

The disposal site lies within the West Kendall Wash drainage area, designated as Basin 1. This is a small drainage of 2.6 mi^2, beginning at the top of the Book Cliffs and running south to the railroad crossing south of the cell. Drainage in this basin tends to run off as sheet flow until concentrated at the railroad crossing. The overland sheet flows tend to produce localized rill erosion, whereas concentrated flows at the railroad crossing tend to produce more notable scour.

The East Branch of Kendall Wash combines with Blaze Wash north of the railroad to form Basin 2. Flows in this basin also go overland until converging at the same railroad crossing, east of the disposal cell site. Runoff from Basins 1 and 2 combines between the railroad and I-70, designated as Basin 3, and forms a small ephemeral stream. Several culverts three feet to four feet in diameter provide drainage for flows west of Blaze Wash to pass under I-70. A pair of six foot diameter culverts allow Blaze Wash to pass under I-70. Together these culverts provide discharge for flows from Basin 3 southward under I-70. At the low point of the Kendall Wash basin a 20 foot diameter culvert allows discharge of Basin 3 to the south under I-70. Given the small capacity of the two foot to three foot culverts, when compared to the 100-year and PMP flood events and the potential for sediment plugging, this analysis is conservatively based on routing all of Basin 3 to the 20 foot culvert crossing.

Crescent Wash is a well-defined ephemeral stream with a basin area of 22.5 mi^2. Crescent Wash is located approximately 2,000 feet west of the disposal cell.

Peak runoff flow rates and flood evaluations for all three basins are determined at specific locations in the vicinity of the Crescent Junction Site for the 100-year, 24-hour storm, and the PMP local storm. Although there are culverts beneath I-70, the capacity of those culverts is small relative to the runoff from the storm events, such that the entire storm runoff was conservatively routed to the west along I-70 in Basin 3.

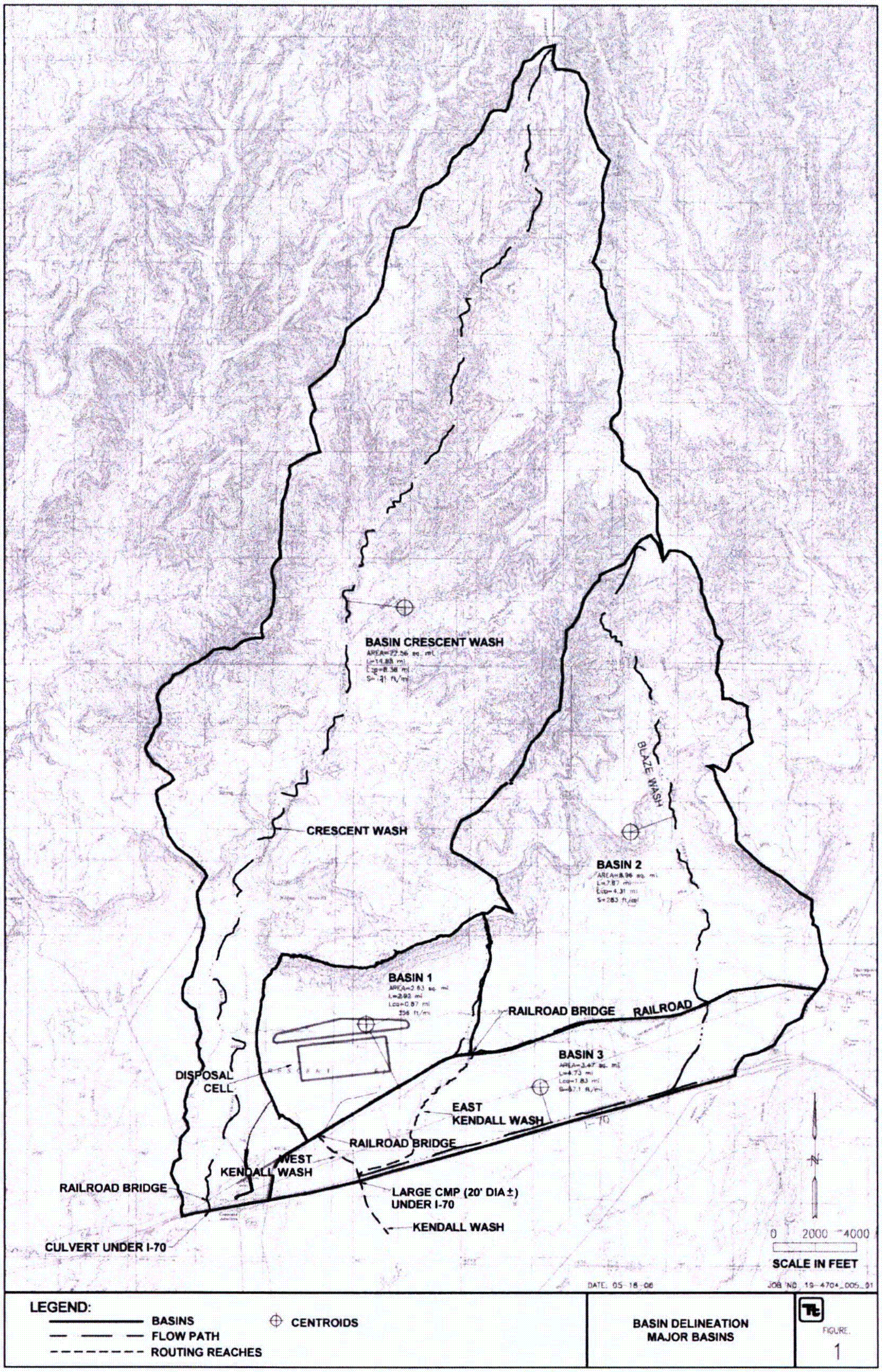


Figure 6–1. Basin Delineations in and Adjacent to the Crescent Junction Disposal Site

6.2 Flooding Determinations

6.2.1 PMP and Distribution

Design storm information is provided in Attachment 1, Appendix E, which calculates the local storm PMP for storms of less than 1 mi^2 to 22 mi^2. This analysis also includes determination of storms in basins covering 1.4, 2.7, 3.5, 9, and 15 mi^2. Additional depth-duration models are developed so that the size of the storm is equivalent to the drainage area contributing to the disposal site. The depth-duration relationships for the modeled storms are summarized in Table 6–1.

Table 6–1. Depth-Duration for Modeled Storms

	Precipitation Depth (inches) for Specified Duration							
	5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
Storm Event								
100-yr, 24-hr	0.53	0.99	1.65	1.82	1.84	1.95	2.16	2.35
PMP – Local								
<1.0 mi^2	4.5	7.1	8.2	8.8	8.9	9.0		
1.4 mi^2	4.3	6.8	8.0	8.6	8.7	8.9		
2.7 mi^2	4.1	6.5	7.9	8.4	8.5	8.7		
3.5 mi^2	4.0	6.2	7.6	8.3	8.5	8.6		
9.0 mi^2	3.4	5.4	6.9	7.6	7.7	8.0		
15.0 mi^2	3.0	4.8	6.4	7.0	7.2	7.7		
22.0 mi^2	2.7	4.3	6.0	6.7	6.9	7.4		

6.2.2 Infiltration Losses

The U.S. National Resources Conservation Service (NRCS) classifies the well-draining sands and sandy loams (Toddler-Ravola-Glenton soil family association) in the disposal site area as Group B soils, which have a range of final infiltration rates of 4 to 8 millimeters per hour (0.16 to 0.31 inch per hour) (NRCS 2007). A 0.15 to 0.3 inch per hour minimum infiltration rate is recommended by the U.S. Bureau of Reclamation (USBR 1987) for Group B soils. For the purpose of this analysis, a value of 0.3 inch per hour is used for modeling the existing undisturbed watershed, and 0.15 inch per hour is used for the cell site. Other loss parameters are noted as follows:

- A U.S. Soil Conservation Service (SCS) curve number (CN) value of 70 was used for Group B soils with sparse vegetation.
- Manning's n value, K_n, representing the hydraulic characteristics of the drainage network, varies with flow; 0.042 was used for the probable maximum flood (PMF), and 0.054 was used for the 100-year flow.
- For the PMF:
  - Loss method in existing watershed: Initial loss of 0.0 inch, constant loss of 0.3 inch per hour.

- Loss method for the disposal cell: Initial loss of 0.0 inch, constant loss of 0.15 inch per hour.
- Loss method for the disposal cell (erosion protection calculations): 0.0 inch per hour.
- Transform method: User-specified unit hydrograph.
- Baseflow method: None.
- Routing reaches: Kinematic wave.
- Meteorology model: PMP calculations, no evapotranspiration, no snowmelt.

- For the 100-year, 24-hour storm:
  - Loss method in existing watershed: SCS CN method with initial loss of 0.86 inch, based on a CN of 70 and constant loss of 0.3 inch per hour.
  - Loss method for the disposal cell: SCS CN method with initial loss of 0.86 inch, based on a CN of 70 and constant loss of 0.15 inch per hour.
  - Transform method: User-specified unit hydrograph.
  - Baseflow method: None.
  - Routing reaches: Kinematic wave.
  - Meteorology model: Precipitation frequency data from U.S. National Oceanic and Atmospheric Administration (NOAA) Atlas 14, no evapotranspiration, no snowmelt (NOAA 2004).

6.2.3 Computation of PMF Events

The methodology for determining the unit hydrograph is detailed in *Design of Small Dams* (USBR 1987) using the dimensionless unit hydrograph data for the Colorado Plateau regions of Arizona, southern California, western Colorado, Nevada, New Mexico, and Utah. Basins in this arid region are generally typified by sparse vegetation, fairly well-defined drainage networks, and terrain varying from rolling to very rugged in the more mountainous areas. The unit hydrograph lag time is defined as:

$$L_g = C\left(\frac{LL_{ca}}{\sqrt{S}}\right)$$

where:

L_g = unit hydrograph lag time, hours. The unit hydrograph lag time is the time from the midpoint of the unit rainfall excess to the time that 50 percent of the volume of unit runoff from the drainage basin has passed the concentration point (USBR 1987).

C = constant = 26 K_n. K_n = average Manning's n value representing the hydraulic characteristics of the drainage basin. K_n is a function of the magnitude of the flows and normally decreases with increasing discharge. K_n values for the PMF are based on recommendations from (USBR 1987), which suggests that the lowest value representative of the region be used. A regional K_n value of 0.042 represents the lower limit of the accepted range for PMF determination and is typical of desert terrain. For other storm events, a higher value is appropriate. K_n ranges from 0.042 to 0.070 in the Colorado Plateau region (USBR 1987). A value of 0.054 is selected for the 25-year and 100-year storm events, representing an area on the White River near Watson, Utah, that is relatively close to the disposal site (Table 3–3 in USBR 1987).

L = the length of the longest watercourse from the point of concentration to the boundary of the drainage basin.

L_{ca} = the length along the longest watercourse from the point of concentration to a point opposite the centroid of the drainage basin.

S = the overall slope of the longest watercourse (along *L*).

Hydrologic parameters and spreadsheets are used to create the basin-specific unit hydrographs for use by the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) (U.S. Army Corps of Engineers (USACE) 2006) models and are presented in Attachment 1, Appendix F. The peak flow rates at each of the design points are summarized in Table 6–2.

Table 6–2. Peak Flow Rates, Major Storm Events

Design Point	Area (mi^2)	Peak Flow Rate (cubic feet per second [cfs])	
		100-yr, 24-hr	PMP - Local
Crescent Wash at RR Bridge and I-70	22.6	5,983	45,197
West Branch Kendall Wash Branch at RR Bridge	2.6	2,135	21,288
Blaze and East Branch Kendal Wash at RR Bridge	9.0	3,453	29,869
East Branch Kendall Wash at I-70 culvert	15.1	5,109	40,835

6.3 Water Surface Profiles and Channel Velocities

The following potential flooding sources were evaluated for this effort: East and West Kendall Wash, Blaze Wash, and Crescent Wash. Analysis of each of these washes extends to a distance sufficient to determine the impacts, if any, on the disposal cell. This requires distances of approximately two miles to three miles for each reach. Flood events are evaluated for the 100-year, 24-hour storm, and the PMP local storm.

6.3.1 Method of Analysis

Hydraulic models are developed to calculate the 100-year and PMF water surface elevations using the USACE HEC-River Analysis System (RAS) (USACE 2005) one-dimensional model assuming fixed bed conditions. Required input includes channel cross sections that are derived from two sources. The first source is from topographic cross-section surveys performed by Keogh Land Surveying of Moab, Utah, during the winter and spring of 2006. The second source is from aerial topographic data with two foot contours, used to supplement survey data. The cross-section points were extracted using AutoCAD 2005 Land Development Desktop. All elevations and topographic mapping are based on NAD 83 and NAVD 88 datum.

Other parameters and modeling methods are noted as follows:

- Manning's n values: A Manning's n value of 0.028 is used for the channel. This selection is supported by comparing these two channels to similar channels in Barns (1967). The overbank n value was determined to be 0.045 and was selected on the type and relative density of vegetation using standard references, including Barns (1967) and Chow (1959).
- Starting water surface elevations: Starting water surface elevations for Crescent Wash and the branches of Kendall Wash are based on normal depth and an energy gradient approximately equal to the starting channel slope.

6.3.2 Results of Flood Analysis

Calculations indicate that the disposal cell location lies outside of the floodplains generated from the 100-year flood event and the PMF from Crescent Wash and the East and West Branches of Kendall Wash. Under PMF conditions, overtopping at the railroad bridges will occur at all three drainages. Overflow from the east branch of Kendall Wash splits with some flow passing over the railroad bridge and some flow turning westerly, flowing along the north drainage swale created by the elevated railroad bed. These flows join with the West Branch of Kendall Wash at the railroad bridge, and the West Branch of Kendall Wash again splits and either overtops the railroad bridge or flows westerly. For the purposes of this analysis it is assumed that the existing culverts under the railroad between East and West Kendall Wash are plugged and have little capacity for reducing the diverted flows running along the north side of the railroad. This is the worst-case scenario in terms of potential for floodwater encroachment at the disposal cell site. The PMP and 100-year floodplains are delineated on Figure 6–2. Detailed hydraulic calculations are included in Attachment 1, Appendix F. Because of differences in the level of accuracy of the two foot contour aerial mapping compared to the surveyed cross sections, there may be slight discrepancies between the model results and the mapped results.

6.4 Erosion Protection Design

The parameters used in the hydrologic analyses for erosion protection of the cell are somewhat more conservative than those in the previous sections. The principal differences are in the watersheds between the top of the Book Cliffs and the disposal cell. The analyses in this section employ a somewhat higher curve number for the Toddler-Ravola-Glenton soil family association, 75 instead of 70, because the vegetation in the area near the Book Cliffs is in generally poorer condition than the average in the larger areas. Compared with the areas of Toddler-Ravola-Glenton soil family association in these smaller watersheds, there are also significant areas of Hanksville family-Badland complex comprising the area near and on the steep slopes of the Book Cliffs. These soils have a higher runoff potential and a lower constant infiltration rate than the Toddler-Ravola-Glenton soil family association. The initial abstractions and constant infiltration rates for these watersheds are, therefore, different from the parameters used in the large scale hydrologic analysis. Soil properties were obtained from the web soil survey (NRCS 2007).

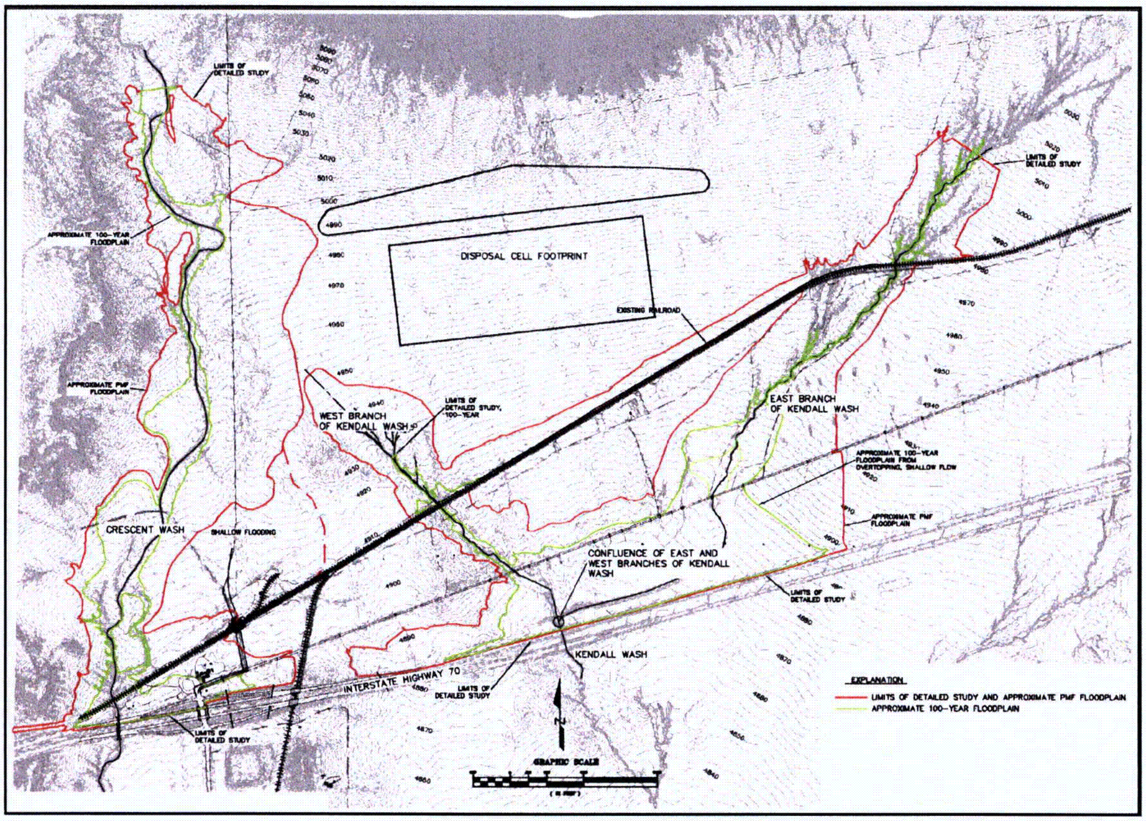


Figure 6–2. PMP and 100-Year Floodplain Delineations for the Crescent Junction Disposal Site

6.4.1 Top Slope and Side Slopes

A plan view of the cell is shown in Figure 6-3. To protect the top surface of the disposal cell against erosion, the surfaces will be covered with rock mulch. The area of the top slope draining to the south will be covered with a six inch layer of rock or rock mulch with a median particle size (D_{50}) of at least 1.8 inches and the area of the top slope draining to the north will be covered with a six inch layer of rock or rock mulch with a D_{50} of at least 1.2 inches. The calculations to determine the D_{50} and thickness of the rock mulch layers on the top and side slopes and on the aprons at the toe of the side slopes are presented in detail in Addendum D, Calculation C-02.

The north side slope, which receives runoff from the north top slope and from rainfall directly on the north side slope, will require a minimum 8.2 inch thick layer of rock mulch with a minimum D_{50} of 4.1 inches while the south side slope will be covered with a minimum 11.6-inches-thick layer of rock with a D_{50} of 5.8 inches. The east and west side slopes will carry substantially equal flows and require rock mulch layers with a minimum D_{50} of 2.3 inches and a minimum thickness of 4.6 inches.

The rock protection placed on the north and south side slopes will overlay a 6-inch-thick sand bedding layer. Rock sizing was estimated using the Safety Factor Method (Nelson et al. 1986) for the top slope, and the Abt and Johnson (1991) Method for the side slopes. Unit flows were calculated based on the PMP event, assuming no infiltration, and a concentration factor of three to account for potential flow channelization. Conservative values were used for input parameters, including a specific gravity for rock of 2.65 and an angle of internal friction of the rock mulch of

37 degrees. In addition, a coefficient of movement of 1.35 was used in the Abt and Johnson (1991) Method to design against rock movement as well as failure. The calculated required rock sizes are based on angular rock that meets NRC durability requirements without oversizing. A summary of the required riprap sizes for erosion protection of the disposal cell slopes is provided in Table 6–3.

Table 6–3. Summary of Erosion Protection Materials

Drainage Area	Unit PMP Discharge (cfs/ft)	Concen-tration Factor	Stone Movement Ratio	D_{50} (in)	Minimum Layer Thickness (in)	Apron Width (10 ft Minimum)	Scour Depth (ft)
South top slope	0.98	3		1.8	3.6		
North top slope	0.54	3		1.2	2.4		
South side slope	1.02	3	1.35	5.8	11.6		
North side slope	0.55	3	1.35	4.1	8.2		
East side slope	0.20	3	1.35	2.3	4.6		
West side slope	0.20	3	1.35	2.3	4.6		
South apron	1.02	3	1.35	11.6	34.7	15	1.66
North apron	0.55	3	1.35	8.2	24.5	10	1.18
East apron	0.20	3	1.35	4.7	14.0	10	0.67
West apron	0.20	3	1.35	4.7	14.0	10	0.67

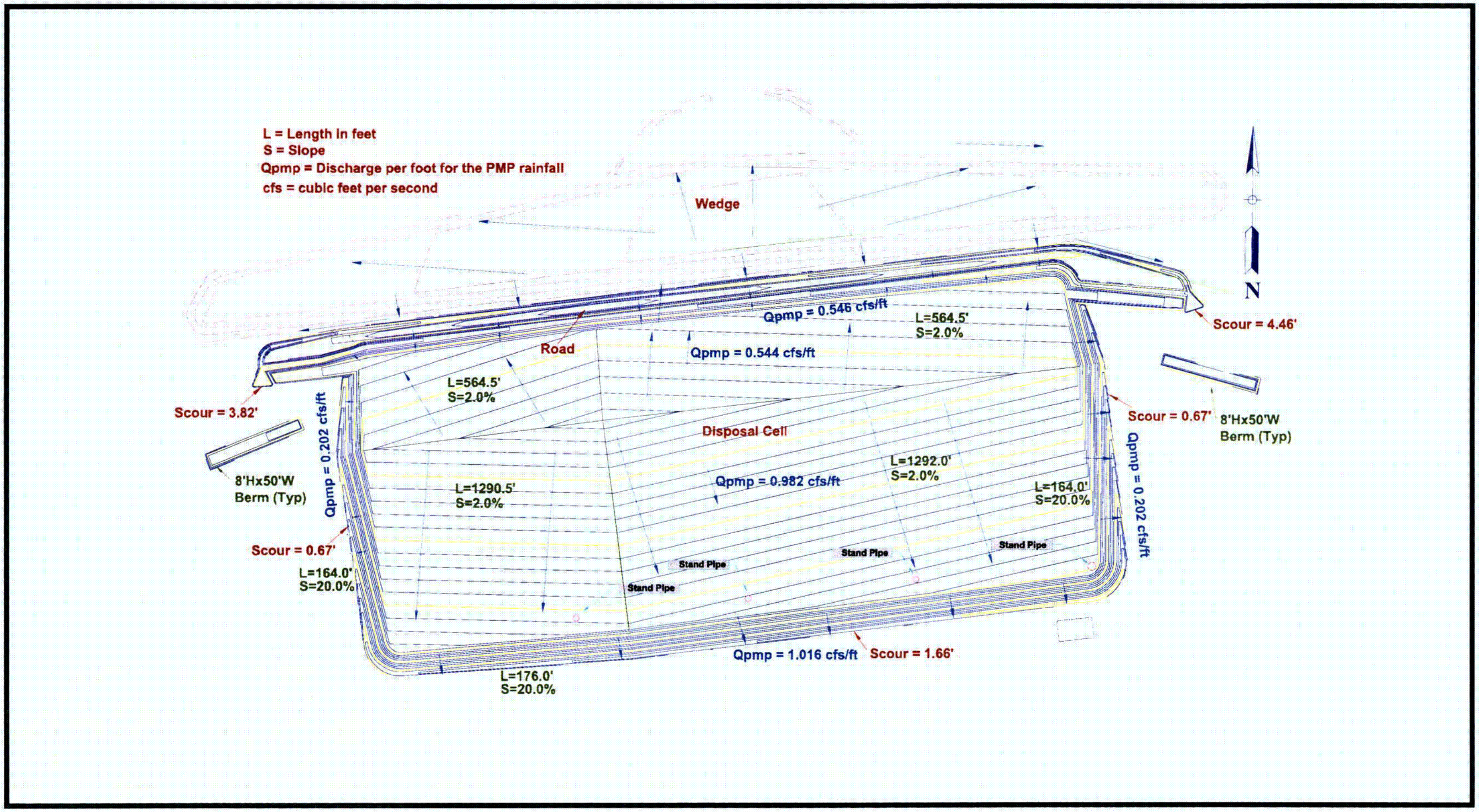


Figure 6–3. Layout of the Cell Showing Dimensions, Flows, and Scour Depths

6.4.2 Toe of Slopes

To protect the toe of the disposal cell, a toe apron will be constructed. The toe area at the base of the south side slope will be protected with 11.6-inch rock (D_{50} minimum). The base of the north slope will require a minimum D_{50} of 8.2 inches. The toe areas at the base of the west and east slopes, which have shorter slope lengths and contributing flow areas, will be protected with a minimum D_{50} of 4.7-inch rock. The thickness of these rock aprons will be a minimum three times the D_{50} and the minimum width will be the greater of 15 times the D_{50} or 10 feet. These rock aprons serve to dissipate flow energy as flow transitions to native ground and provide protection against scour. A summary of the required riprap sizes for erosion protection of the disposal cell toe aprons is provided in Table 6–3.

6.4.3 North Side of Cell

The north side of the disposal cell will experience runoff from the area between the Book Cliffs and the cell (Basins A and B, Figure 6–4). Protection from this runoff is provided by placing the excess material excavated during the construction of the disposal cell between the Book Cliffs and the disposal cell to divert flow around the cell. This material (the wedge) will be placed as shown in Figure 6-3 and compacted to a density of 90 percent of the laboratory determined maximum density in accordance with ASTM D 698. An access road between the cell and the wedge will be left in place after construction of the disposal cell is complete. Runoff from the south side of the wedge will flow to the east and west in a ditch along the north side of this road and runoff from the north side of the cell will flow east and west along the south side of the road.

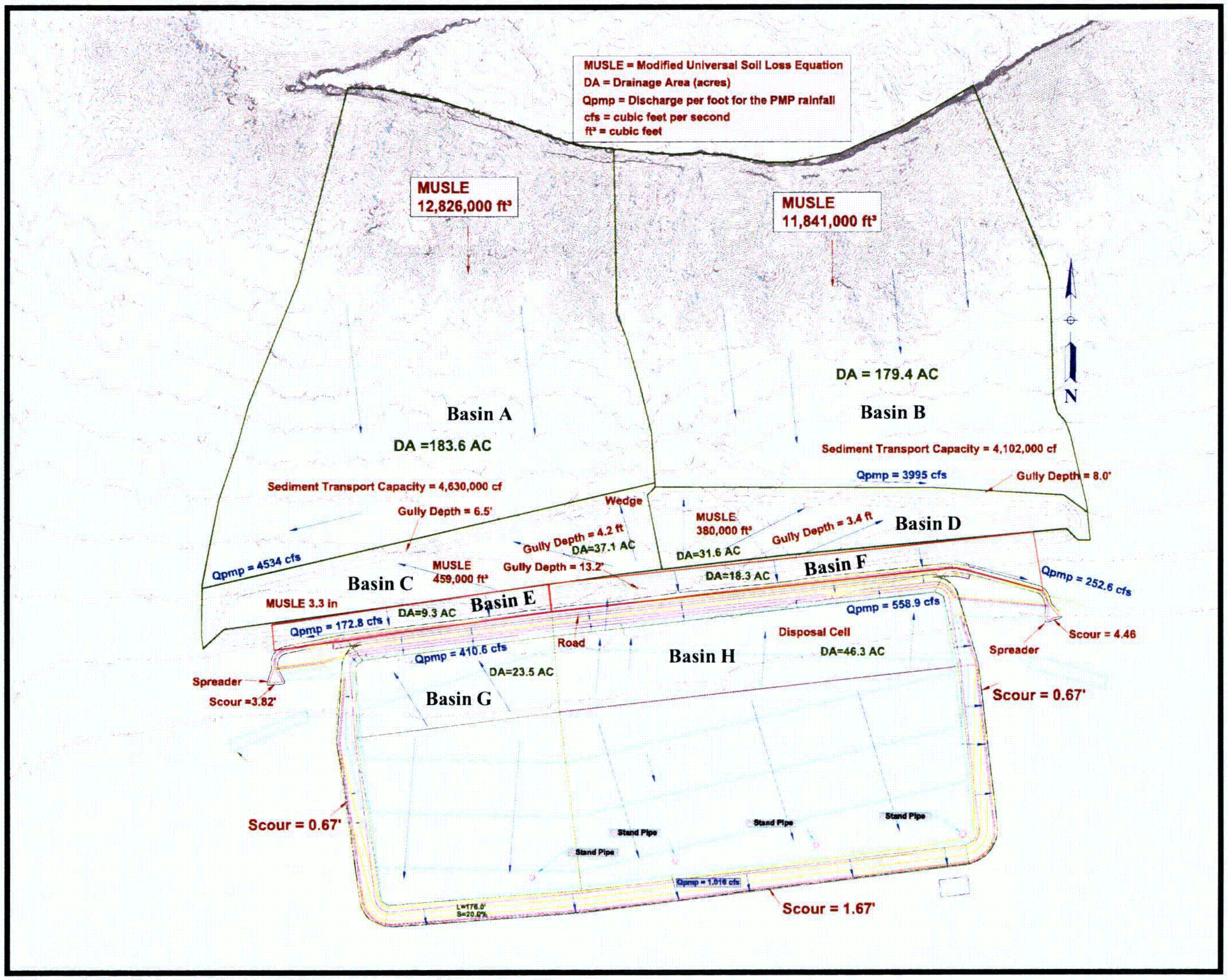


Figure 6–4. Layout of the Cell, Wedge, and Drainage Basins North of the Wedge.

6.4.3.1 Wedge

As shown in Figure 6–3, a wedge consisting of approximately 3 million yd^3 of soil excavated from the disposal cell will be placed between the Book Cliffs and the disposal cell to divert runoff from the Book Cliffs area around the cell. It is critical that the wedge remain intact and perform this function for the 1,000-year design life of the cell. Several possible mechanisms by which the cell could fail have been assessed. These are

1. Erosion of the wedge by drainage from the watersheds to the north as the water flows to the east and the west along the north side of the wedge. This erosion will be mitigated by sediment supply from the Book Cliffs and the area between the cliffs and the wedge.

2. Uniform erosion of sediment from the top of the wedge by precipitation falling directly on top the wedge.

3. Concentration of flow from precipitation forming gullies as it flows across the top of the wedge and down the sides to the northeast and northwest.

4. Uniform erosion of sediment from the south side of the wedge by precipitation falling directly on the south side slope of the wedge.

5. Concentration of flow from precipitation on the south slope of the wedge forming gullies as it flows to the south into the drainage along the north side of the access road. Detailed results are presented in Section 6.4.3.2 with the discussion of the area between the disposal cell and the wedge.

Detailed calculations of the processes analyzed are described in Calculations C-03 and C-04 of Addendum D.

<u>Erosion Along the North Side of the Wedge</u>

The potential for erosion from the north side of the wedge by runoff from the watersheds to the north was evaluated using methods for estimating the sediment transport capacity of flow in open channels described in NRC guidance (Johnson 2002). Estimates of sediment supply from these watersheds were made using the Modified Universal Soil Loss equation (MUSLE) (Nelson et al. 1986). The procedure was to:

- Compute the runoff from the watersheds between the top of the Book Cliffs and the wedge, Basins A and B, and from the top of the wedge, Basins C and D, for a series of design storms with return intervals from one year to the PMP.
- Calculate the potential sediment transport in a hypothetical channel that carries the runoff along the north side of the wedge and around the disposal cell using methods from Johnson 2002. A cross section of the northern edge of the wedge is shown in Figure 6–5.
- Calculate the sediment yield of the areas between the Book Cliffs and the wedge using the MUSLE (Nelson et al. 1986).
- Compute the net potential sediment addition to or subtraction from the wedge.

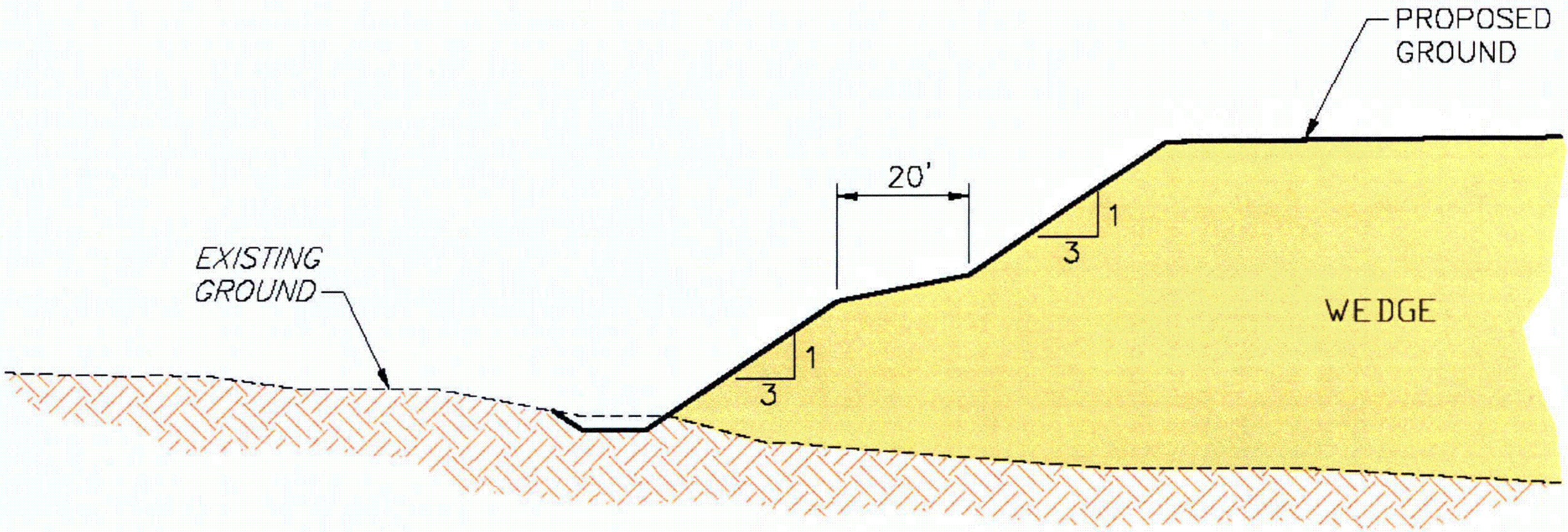


Figure 6–5. Cross Section of the North Edge of the Wedge and Existing Ground

Sediment Transport Potential

The storms selected for the erosion potential analysis are listed in Table 6–4. The series of storms for the runoff calculations was developed from the hydrology data in Attachment 1, Appendix E, and from NOAA Atlas 14 (NOAA 2004). The number of storms of each depth was chosen conservatively as follows.

- A storm with rainfall equal to or greater than the 1,000-year storm occurs on the average once every 1,000 years. Because the amount of rainfall may be anywhere between the 1,000-year storm and the PMP, the PMP was used for this storm.
- A storm with rainfall equal to or greater than the 500-year storm occurs on the average twice every 1,000 years. Because the amount of rainfall may be anywhere between the 500-year storm and the 1,000-year storm, the 1,000-year rainfall was used for this storm. Because the PMP has already accounted for one storm greater than the 500-year storm, only one 1,000-year storm was used.
- A storm with rainfall equal to or greater than the 200-year storm occurs on the average five times every 1,000 years. Because the amount of rainfall may be anywhere between the 200-year storm and the 500-year storm, the 500-year rainfall depth was used for this storm. Because two larger storms have already been applied, three 500-year storms were used.

Following this logic through storms of all return periods included in Atlas 14, the resulting in the distribution of rainfall and number of storms are listed in Table 6–4. All storms represent the 24-hour precipitation except for the PMP, which is a 6-hour depth.

Table 6–4. Distribution of Storms Used in Computing Sediment Transport Capacity Over a 1,000-Year Time Period

Return Interval Represented (yrs)	Return Interval Employed (yr)	Precipitation (in)	Number of Storms Equal or Greater than the Interval Represented	Number of Storms Employed
1000	PMP (6 hour)	9.00	1	1
500	1000	3.73	2	1
200	500	3.15	5	3
100	200	2.58	10	5
50	100	2.35	20	10
25	50	2.12	40	20
10	25	1.91	100	60
5	10	1.63	200	100
2	5	1.42	500	300
1	2	1.16	1000	500
< 1	1	0.93	Unknown	1000

The hydrologic analysis was performed as described in Section 6.2 with some differences in parameters as described below.

1. The watersheds between the Book Cliffs and the wedge are composed of both the Toddler-Ravola-Glenton (USDA 2007) soil family association, which are hydrologic Group B soils

and the Hanksville family Badland complex, which are Group C soils. A runoff CN of 75 was assigned to the Group B soils as herbaceous arid rangeland in fair to poor condition and a CN of 87 to the type C soils for the same use in poor condition (TR-55). The composite CNs are 79.4 and 81.1 for the western and eastern drainages, respectively. The resulting initial abstractions are 0.52 and 0.47 inches. Using a constant infiltration rate of 0.3 in/hr for the Group B soils and 0.03 in/hr for the Group C soils (USDA 2007) results in composite constant infiltration rates of 0.20 in/hr and 0.16 in/hr for the eastern and western drainages, respectively.

2. The wedge is constructed of compacted soil so that natural soil properties and the USBR unit hydrograph transform approach are not appropriate. The SCS unit hydrograph approach was used to transform excess rainfall into runoff. An initial abstraction of 0.2 inches and a constant infiltration rate of 0.1 in/hr were assumed for compacted soil.

Based on field observations of West Kendall Wash, the runoff was assumed to flow along the north side of the wedge in hypothetical trapezoidal channels with bottom widths of three feet and a side slope of 1.5:1. The slopes of the channels are 0.007 to the east and 0.009 to the west as determined from the topography of the site and the configuration of the wedge. A table was constructed of potential sediment transport in a 5-minute period as a function of discharge in each channel. The flow in each 5-minute period of a runoff hydrograph was then used to interpolate the potential sediment transport during each five minute increment. The sediment transport of each hydrograph was then computed as the sum of these 5-minute contributions.

NRC guidance (Johnson 2002) states that a runoff-to-rainfall ratio of 0.127 provides a reasonable estimate for the arid and semi-arid regions of the western United States. Because the total calculated runoff from the storms listed in Table 6–4 is less than 12.7 percent of the average annual rainfall of 9.97 inches at Thompson Springs (NOAA 2004) (approximately five miles east of the disposal cell), additional runoff and erosion were calculated. It was assumed that the runoff unaccounted for by the listed storms had a sediment concentration equal to that of the one-year storm. The additional erosion potential was computed as the product of the additional volume of runoff and the computed concentration of sediment in the runoff from the 1-year storm.

Sediment Supply

The runoff from the area between the top of the Book Cliffs and the wedge will transport sediment toward the wedge. The total sediment loss from the two watersheds delineated over a 1,000-year period can be estimated using the MUSLE (Nelson et al. 1986).

The equation is:

$$A = R \times K \times LS \times VM$$

where:

A = soil loss in tons per acre per year.
R = rainfall factor.
K = soil erodibility factor.
LS = topographic factor.
VM = dimensionless erosion control factor relating to vegetative and mechanical factors.

An average slope of 3.5 percent was used in the calculations. This is a representative slope for the area between the wedge and the base of the Book Cliffs. The soil loss (sediment supply) from the Book Cliffs area is most likely underestimated since the slope from the base to the top of the Book Cliffs is 40 to 50 percent and the erodibility factor of the soil in that area is comparable for the two soil types in the watershed. More sediment than calculated should be eroded from this area, but much of the additional sediment will be deposited as the slope flattens near the wedge.

The relative sediment yield of a more realistic watershed shape has been assessed with the Revised Universal Soil Loss Equation (RUSLE) using the computer program RUSLE2 (NRCS 2001). In this simulation three slopes were used, 1,000 feet at 40 percent to represent the Book Cliffs, 800 feet at 3.5 percent and 800 feet at 2.5 percent to represent the area between the base of the Book Cliffs and the wedge. A RUSLE2 simulation was also performed with the same three segments, but with each having a slope of 3.5 percent to mimic the calculations performed using the MUSLE. These calculations yield more than three times the sediment delivery at the north edge of the wedge with the varying slope than with the single slope of 3.5 percent indicating that the assumption of a single 3.5 percent slope in the MUSLE calculation was conservative.

The MUSLE was also used to calculate the volume of sediment that would be lost from the top of the wedge to the area on the north side of the wedge. The volumes of sediments over a 1,000-year period calculated with the MUSLE, and the sediment transport potential along the north side of the wedge are summarized in Table 6–5.

Table 6–5. Sediment Budget for the North Side of the Wedge

Area	Sediment Transport Capacity (ft^3)	Sediment Yield from MUSLE (ft^3)
Channel along wedge to the west	4,630,000	
Channel along wedge to the east	4,102,000	
Western area between Book Cliffs and the wedge		12,826,000
Eastern area between Book Cliffs and the wedge		11,841,000
Western portion of the top of the wedge		459,000
Eastern portion of the top of the wedge		380,000
Total sediment yield toward the west portion of the wedge		13,285,000
Total sediment yield toward the east portion of the wedge		12,221,000
Ratio of sediment supply from Book Cliffs to channel sediment transport capacity (west)	2.8:1	
Ratio of sediment supply from Book Cliffs to channel sediment transport capacity (east)	2.9:1	

These results indicate that the water flowing along the north side of the wedge to the west and the east does not have sufficient sediment transport capacity to remove the supply of sediment from the areas between the top of the Book Cliffs and the wedge. The northern edge of the wedge is expected to expand northward during the 1,000-year life of the disposal cell and offer increasingly more protection to the cell as time passes. Even discounting the sediment supply from the north, the total sediment transport potential over 1,000 years is only about 12 percent of the volume of the wedge.

Erosion from the Top of the Wedge

Due to the nearly flat slope on top of the wedge, the predicted erosion from the top of the wedge, using the MUSLE, is only 3.3 inches over a 1,000-year period. Since the height of the wedge ranges from 28 to 48 feet, this is an insignificant depth of erosion.

Gully Formation on the Wedge

In addition to potential erosion of the wedge by runoff from the Book Cliffs area and sheet and rill erosion from precipitation directly on top of the wedge, runoff from the top of the wedge is expected to form gullies on the top and on the steep slopes on the north side as the runoff from the top of the wedge flows to the northwest and the northeast. The potential depth of these gullies can be estimated with an approach detailed in NRC guidance (Johnson 2002). The estimated maximum depth of gully incision is

$$D_{\max} = G_f L_{total} S$$

where:

G_f = function of the total volume of runoff and the embankment height.
L_{total} = maximum length of flow contributing to gully formation.
S = the original slope of the embankment.

The results of these calculations are summarized in Table 6–6.

Table 6–6. Summary of Calculations of Gully Depths on the Wedge

Description	Top Slope West	Side Slope West	Top Slope East	Side Slope East
Height of embankment (ft)	10	18	8	22
Horizontal length of embankment (ft)	1339	95	1254	92
Length of embankment along slope (ft)	1339	96.7	1254	94.6
Maximum gully depth (ft)	4.2	6.5	3.4	8
Gully width at maximum depth (ft)	7.7	12.7	5.9	16
Maximum distance from top of slope (ft)	248	4.1	204	4.7

Runoff from precipitation on the south side slope is also expected to form gullies on these steep slopes. The calculation of these gully depths is described in Section 6.4.3.2 and summarized in Table 6–9.

6.4.3.2 Drainage Between the Wedge and the Cell

An access road between the cell and the wedge (Figures 6–6 and 6–7) will be left in place after construction of the disposal cell is complete. Runoff from rainfall on the north slope of the cell (Basins G and H) will flow east and west in a ditch on the south side of the access road. Runoff from rainfall on the south slope of the wedge (Basins E and F) will flow east and west in a ditch on the north side of the road. The sides of the ditch on the south side of the road will be the north slope of the cell and the south slope of the road berm. The bottom of the ditch will be the north toe apron of the cell. The ditch on the north side of the road will be formed by the north side of the road berm, the south slope of the wedge, and a 15-foot wide flat bottom.

The ditches on the north side of the road will continue for several hundred feet to the east and west of the cell boundary where they will turn southerly and discharge via 100 foot wide spreaders. The ditches on the south side of the road will increase in width from 15 to 20 feet at the boundary of the disposal cell to carry the flow to the spreaders along the north side of berms. The berms will ensure that if there is any spillover from the ditches, the flow will still be routed to the spreaders. The configuration of these ditches and berms is shown in Figures 6–6 and 6–7.

Two drainage areas were delineated between the wedge and the access road draining to the southwest and to the southeast (Basins E and F). Two more were delineated between the watershed divide on top of the cell and the access road to the northwest and the northeast (Basins G and H). Pertinent properties of the four drainage areas are presented in Table 6–7.

Table 6–7. Drainage Area Characteristics

Drainage Area	Area (acres)	Max Flow Length (ft)	Time of Concentration (min)	Lag = 0.6 Tc
Southwest wedge side slope (Basin E)	9.3	2062	23.38	14.0
Southeast wedge side slope (Basin F)	18.3	3470	35.53	21.3
Northwest portion of cell (Basin G)	23.5	1471	25.38	15.2
Northeast portion of cell (Basin H)	46.3	2891	41.96	25.2

The calculated depths of the gullies that will form on the south side slope of the wedge over a period of 1,000 years are substantial, ranging from 9.6 to 13.2 feet. Nonetheless, these gullies are not expected to threaten the integrity of the wedge. In each case the height of the wedge is more than three times the calculated gully depth and the minimum north-south dimension of the wedge is about 120 feet, much greater than the expected gully depth.

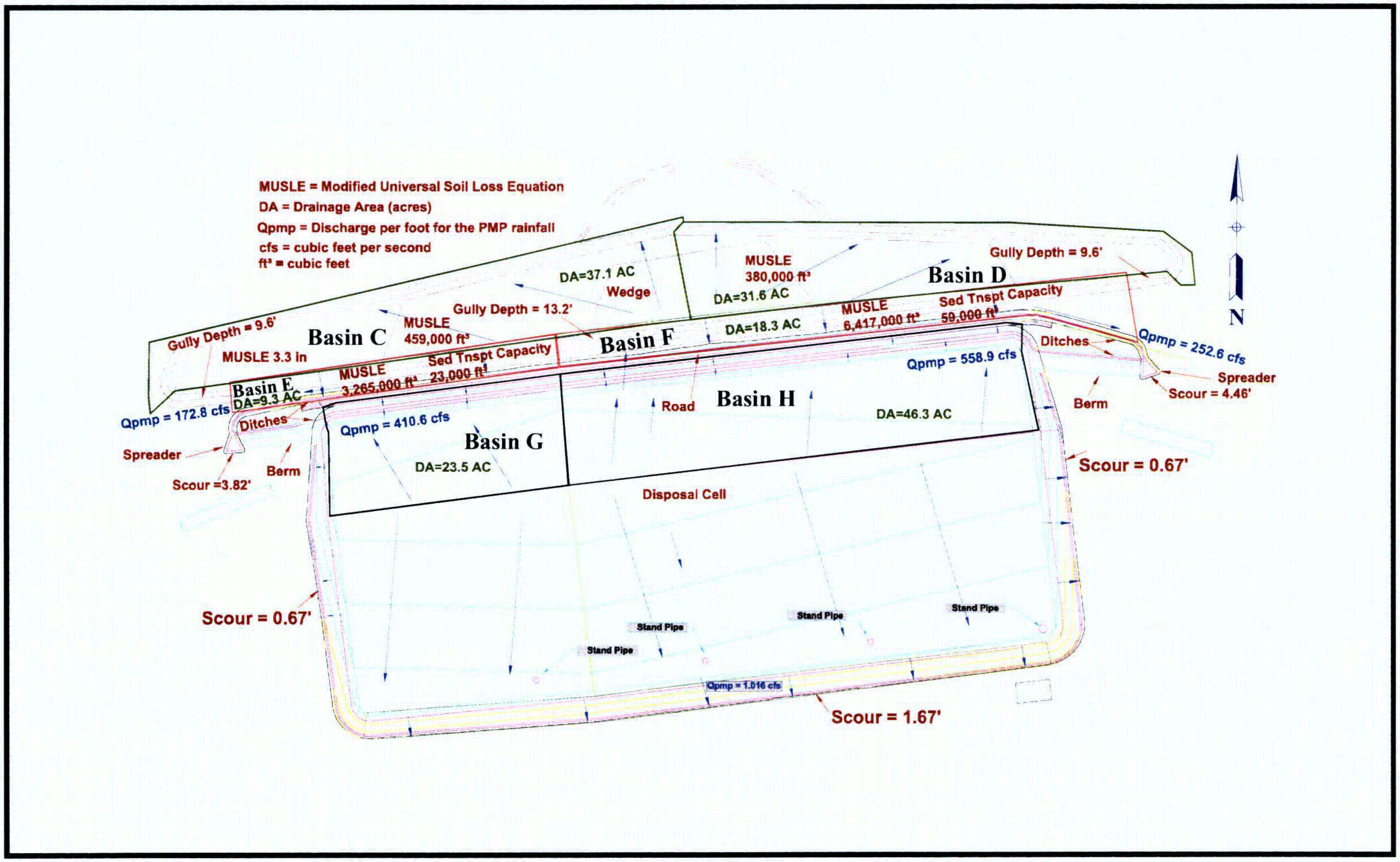


Figure 6–6. Configuration of the Cell, the Wedge, and the Drainage Between the Cell and the Wedge

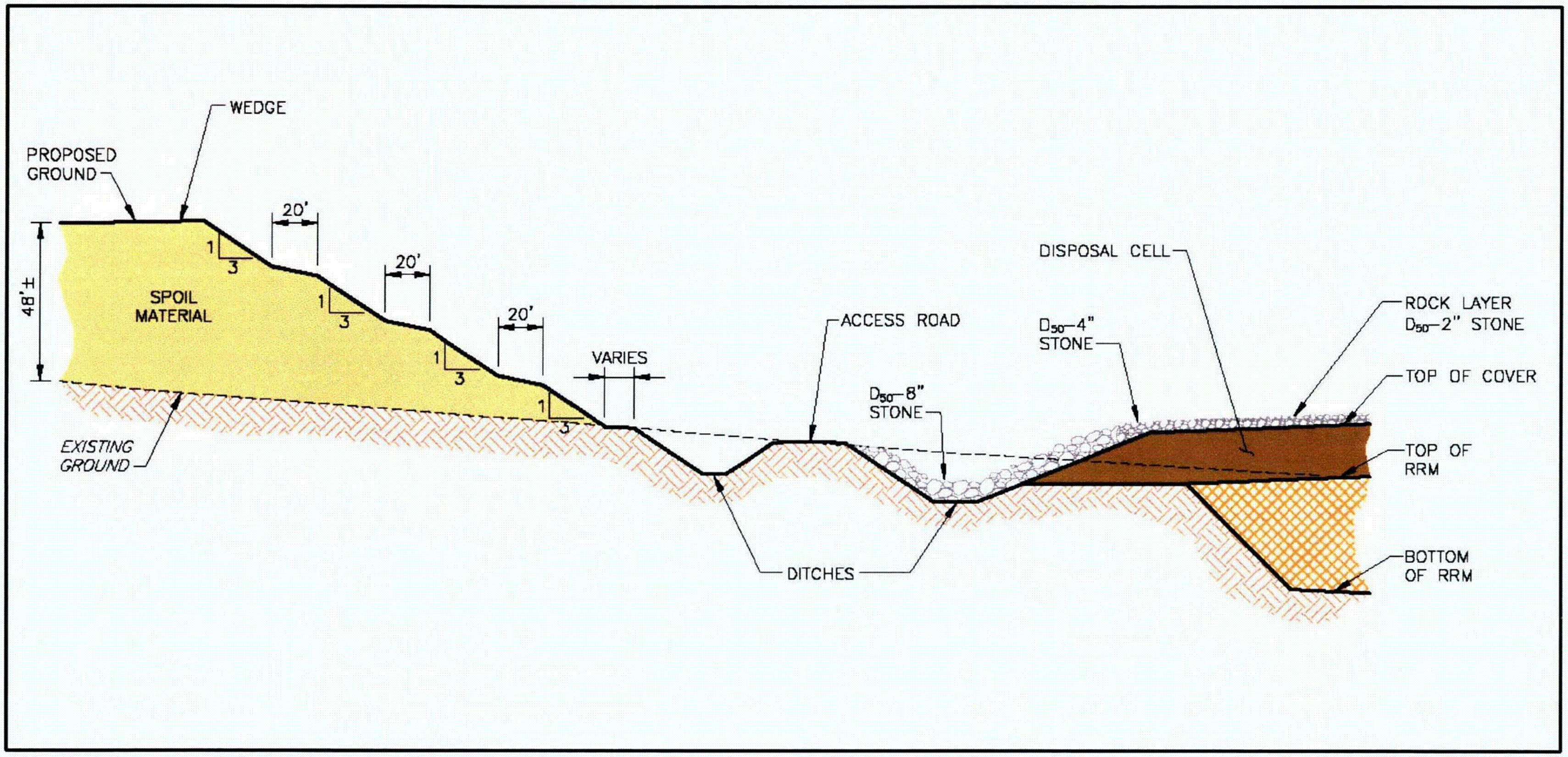


Figure 6–7. Cross Section Through the North Slope of the Cell to the Top of the Wedge

Table 6–9. Summary of Calculations of Gully Depths Between the Cell and the Wedge

Description	End of South Side Slope	Center of South Side Slope
Height of embankment (ft)	30	48
Horizontal length of embankment (ft)	118	176
Length of embankment along slope (ft)	121.8	182.4
Maximum gully depth (ft)	9.6	13.2
Gully width at maximum depth (ft)	20	28.5
Maximum distance from top of slope (ft)	35	58

While the predicted depths of gullies that will form on the south side slope of the wedge over a period of 1,000 years are substantial (ranging from 9.6 to 13.2 feet), the gullies are not expected to threaten the integrity of the wedge. In each case the height of the wedge is more than three times the calculated gully depth and the minimum north-south dimension of the wedge is approximately 120 feet, much greater than the expected gully depth.

Rock in Channels and on the North Side of Berms

The channels on the north side of the access road carrying runoff from the south side slope of the wedge to the east and to the west will not be armored for most of their lengths because the sediment supply from the south side of the wedge will far exceed the sediment transport capacity of flow in the ditches. Beginning approximately 100 feet upstream of each end of the access road, rock will be placed in the channels to protect them against erosion from that point to the spreaders that terminate the channels. If the channels fill with sediments, the flow will leave the channels and flow southward toward and over the access road shown in Figures 6–6 and 6–7. In addition, flow from the top of the cell and the area south of the access road (north of the cell) will flow to the east and to the west in trapezoidal ditches with 3:1 side slopes and a bottom width increasing from 15 to 20 feet. The flow in these ditches will continue along the north side of berms that extend from the cell side slopes to the spreaders. Any overflow from the ditches north of the road will also be intercepted by these ditches and berms and routed to the spreaders.

The peak flow resulting from the PMP in each of these areas has been calculated using the SCS unit hydrograph technique with an initial abstraction of 0.0 inches and a constant infiltration rate of 0.1 inches/hour. The results of these calculations are included in Table 6–10.

Table 6–10. Peak Flows from the Area Between the Wedge and the Cell for the PMP

Peak Flow from PMP	South Side of Wedge (West) (Basin E)	South Side of Wedge (East) (Basin F)	Flow from Cell (West) (Basin G)	Flow from Cell (East) (Basin H)
Drainage area (acres)	9.3	18.3	23.5	46.3
Time of concentration (min) (T_c)	23.4	35.5	25.4	42.0
Lag (min) = $0.8T_c$	14.0	21.3	15.2	25.2
Peak flow (cfs)	172.8	252.6	410.6	558.9

The D_{50} for stone erosion protection was determined using the Safety Factor Method (Nelson et al. 1986). The results of these calculations are presented in Table 6–11. Each of the channels north of the road berm is assumed to have a bottom width of 10 feet and side slopes of 3:1. The flow from the cell flows along the north side of the berms with the side slope of the channel being 3:1 along the berm and 2.3 percent (the natural ground slope) on the opposite side.

Table 6–11. D_{50} of the Stone Required for Erosion Protection

D_{50} for Erosion Protection	South Side of Wedge (West)	South Side of Wedge (East)	Flow from Cell (West)	Flow from Cell (East)
Peak flow (cfs)	172.8	252.6	410.6	558.9
Channel slope	.0094	.0076	.0089	.0063
D_{50} (inches) on 3:1 side of channel	3.3	3.4	3.8	3.3
D_{50} (inches) on bottom of channel	2.6	2.6	2.9	2.5
Portion of channels north of the road after they have turned southerly				
Channel slope	.0175	.0175		
D_{50} (inches) on side of channel	5.8	7.2		
D_{50} (inches) on bottom of channel	4.5	5.6		

Rock and Scour at Spreader Outlets

Flow from the channel north of the access road and from the top of the cell will combine at the spreader for discharge onto natural ground. The peak flows from the PMP have been added to estimate the peak flow from each spreader. To obtain the flow per unit width, the peak flow has been spread over a width of 100 feet. To account for potential channelization in the rock of the spreaders, the unit flow has been multiplied by three for calculation of the required D_{50} of rock for erosion protection and potential scour depth at the outlet of each spreader. The D_{50} was calculated using the Safety Factor Method assuming a channel with 3:1 side slopes, a one foot bottom width and a channel slope of 2.3 percent. Scour was calculated using the Federal Highway Administration culvert scour equations (DOT 1983) assuming flow in a V-shaped ditch with 2:1 side slopes. The results are summarized in Table 6–12.

Table 6–12. Calculated Depth of Scour at Spreader Outlets

	West Spreader	East Spreader
Peak flow from channel (cfs)	172.8	252.6
Peak flow along berm (cfs)	410.6	558.9
Combined peak flow (cfs)	583.4	811.5
Concentration factor	3	3
Design flow (cfs/ft)	17.50	24.35
Minimum rock D_{50} (in)	4.5	5.2
Estimated scour depth (ft)	3.82	4.46

6.4.3.3 Summary of Wedge Longevity Analyses

Calculations C-03 and C-04 have been performed to assess whether the wedge will continue to protect the cell during the 1,000-year design life. Three possible processes by which the integrity of the wedge might be compromised have been considered.

1. Erosion of the wedge by runoff from the area between the Book Cliffs and the wedge will tend to erode the wedge as it is routed to the southwest and northwest around the wedge and the disposal cell. The results of these calculations indicate that the total sediment carrying capacity of the runoff as it flows around the wedge is approximately 12 percent of the volume of the wedge. In addition, the sediment supply from the Book Cliffs area computed from the MUSLE will be approximately three times the sediment transport capacity of the flow around the wedge, resulting in a net gain in the volume of the wedge over the design life of the disposal cell.
2. Precipitation falling directly on the top of the wedge will run off toward the northeast and the northwest. This runoff will erode the wedge from the top. Application of the MUSLE to estimate the volume of sediment lost from the wedge through this mechanism indicates that the wedge will be reduced in average height by about three inches to four inches. With a design height of the wedge ranging from approximately 28 feet to 48 feet, this loss of soil will not threaten the integrity of the wedge.
3. The third mechanism considered is concentration of flow as it runs off the top of the wedge and the consequent formation of gullies both on top of the wedge and on the steep slopes to the northwest, the northeast, and the south. The calculations show that the gullies formed by runoff would not pose a serious threat to the integrity of the wedge.

Based on these calculations, the wedge will protect the disposal cell from runoff from the areas to the north and continue to function over the 1,000-year design life of the cell.

6.5 Rock Durability

Several sources of erosion protection rock have been evaluated and are potentially suitable for use on the cell. Rock used for erosion protection on the disposal cell must meet the specified scoring criteria listed in Table 6–13 to ensure meeting NRC durability requirements.

Table 6–13. NRC Table of Scoring Criteria For Rock Quality

Laboratory Test	Weighing Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
Specific Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.30	2.25
Absorption, %	13	5	2	0.10	0.30	0.50	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
LA Abrasion, % (100 revolutions)	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmitt Hammer	11	13	3	70	65	60	54	47	40	32	24	16	8	0

Notes

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642, Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, 1982.
2. Weighing Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G.W. Dupuy, Engineering Geology, July 1965. Weighing factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighing factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR2642, so that proper correlations can be made.

Acceptable Rock Scores

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 cell, 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 D_{50} 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.

Rock Oversizing

Oversize rock as follows:

- 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 D_{50} of the rock shall be increased by the oversizing percent. For example, a rock with a 10 percent oversizing factor and a D_{50} of 12 inches will increase to a D_{50} of 13.2 inches.
- The final thickness of any layer of oversized rock shall increase proportionately to the increased D_{50} rock size. For example, a layer thickness equals twice the D_{50}, such as when the plans call for 24 inches of rock with a D_{50} of 12 inches, if the stone D_{50} increases to 13.2, the thickness of the layer of rock with a D_{50} of 13.2 should be increased to 26.4 inches.

6.6 Rock Sources

Determination of the rock sources to be used for disposal cell aggregate and riprap requirements is an important component of the design. After selection of Crescent Junction as the site for the disposal cell and prior to final cell design, a number of potential rock sources were evaluated. Results from that investigation are provided in the *Evaluation of Aggregate and Riprap Source Areas for Rock Cover of Crescent Junction, Utah, Disposal Cell* (DOE 2007). During the final design process, two additional sites were identified and considered for the final rock source selection, including one aggregate site (Silliman Quarry) and one riprap site (Fremont Junction). This section provides a brief review of the site characteristics and test results for the rock sources initially investigated by DOE and a more detailed discussion of site evaluations recently conducted at the Silliman and Fremont Junction sites.

During the initial DOE evaluation of potential rock sources, two areas were evaluated as potential aggregate sources and five areas were evaluated as potential riprap sources (Figure 6–8). Potential rock sources were evaluated primarily based on the design requirements for rock size, volume, and durability. Land ownership and distance from the source to the disposal cell were also considered. The distance from more recently identified potential sources to the cell ranged from approximately 5 to 40 miles. More distant, existing quarries were also evaluated, including LeGrand Johnson Pit for aggregate and Papoose Quarry for riprap. Potential aggregate areas investigated were the Green River Terrace site and LeGrand Johnson Pit. Potential riprap areas investigated were the Valley City, Little Valley, Tenmile Wash, Blue Hills Road, Cane Creek Anticline, and Papoose Quarry sites. The aggregate sites consist of alluvial or terrace deposits and the riprap sites were either sillicified sandstone/conglomerate or limestone deposits.

During this evaluation, rock samples were collected at the Green River Terrace aggregate site and the Valley City site for riprap. Test results of samples collected at the Valley City site were deemed representative for the Little Valley, Tenmile Wash, and Blue Hills Road deposits due to the similarity in rock type and geologic unit. Testing had been conducted on the Papoose Quarry materials in 2002 and testing of similar materials to the Cane Creek deposit had been conducted in 1996.

Rock samples were tested based on NRC quality criteria and were tabulated in Table 11 in *Evaluation of Aggregate and Riprap Source Areas for Rock Cover of Crescent Junction, Utah, Disposal Cell* (DOE 2007a). The NRC scores from the testing at both of the aggregate sites were above the 50 percent requirement for use on the cell cover. Of the rock sources considered for riprap, only the Papoose Quarry deposit scored above 80 percent on the NRC evaluations.

Scores for remaining riprap sources ranged from 67.5 percent to 76 percent, and would therefore require oversizing for use in the critical areas of the cell.

During the design phase of the project, site evaluations were conducted at the Silliman Quarry and Fremont Junction sites (Figure 6–9). The Silliman Quarry deposit is a terrace deposit consisting of a variety of lithologies and is being investigated as a potential aggregate source. The Fremont Junction deposit is an alluvial deposit being investigated as a potential riprap source.

Rock samples were collected in February 2008 at the Silliman site and submitted for NRC quality criteria testing. As part of the sampling process, a quantitative evaluation of the Silliman site was also conducted to further evaluate the nature of the deposit with regards to rock size, quantity, and quality. Sampling of the site was conducted to quantify the size of the individual rocks in the deposit, determine the lithologies of the larger rock sizes, and evaluate the uniformity of the deposit qualitatively. A total of six sample pits were excavated with a trackhoe at the Silliman site, including three on the lower terrace and three on the middle terrace. The Silliman site is privately owned and an upper terrace was not excavated due to the relatively small area that the landowner would potentially make available for quarrying.

Bucket-size samples were collected with the trackhoe at 3-foot intervals to either bedrock or the maximum excavation depth of the trackhoe (roughly 20 feet). A handheld shovel was then used to obtain representative samples from these piles for evaluation of rock size and lithology. Visual inspection of the samples collected at the initial pit location indicated little variability in size or lithology with depth. Therefore, after shovel collection, these samples were composited prior to final size and lithlogic evaluations. Rocks were initially segregated based on size (sediment–two inches, two to four inches, and greater than four inches) and visual estimates of size percentages were made (Table 6-14). For rocks in the two inches to four inches and four inches or greater categories, samples were then segregated based on lithology. Percentages of rocks were then visually estimated based on lithology. The lithologies observed in the deposit are presented in Table 6–14. Of these, only the tan, friable, and fine to medium-grained sandstone appeared to be of obviously poor quality for use on the cell cover. The percentage of this sandstone of the total for rocks four inches or greater was 10 to 15 percent. For the two to four-inch category, this percentage increased to approximately 20 to 25 percent.

The privately owned portion of the Silliman deposit is approximately 140 acres; the area of lower terrace on the property is roughly 30 acres. The sample excavations at the lower terrace began at the eastern edge of the site and proceeded to the west. The material from the first two excavations was very similar in rock size and lithologic distribution. The most western excavation contained lower percentages of cobbles four inches or greater. At this location, a representative sample was collected and sorted by size. A visual estimate of the four inches or greater cobbles was approximately 10 percent of the total. On the middle terrace, the amount of sediment overburden increased when moving north, away from the Green River. Rock size percentages for four inches or greater cobbles in the middle terrace deposits were estimated to be between 10 percent and 25 percent. If necessary, quarrying on this terrace should begin closer to the river and proceed in an east-west direction.

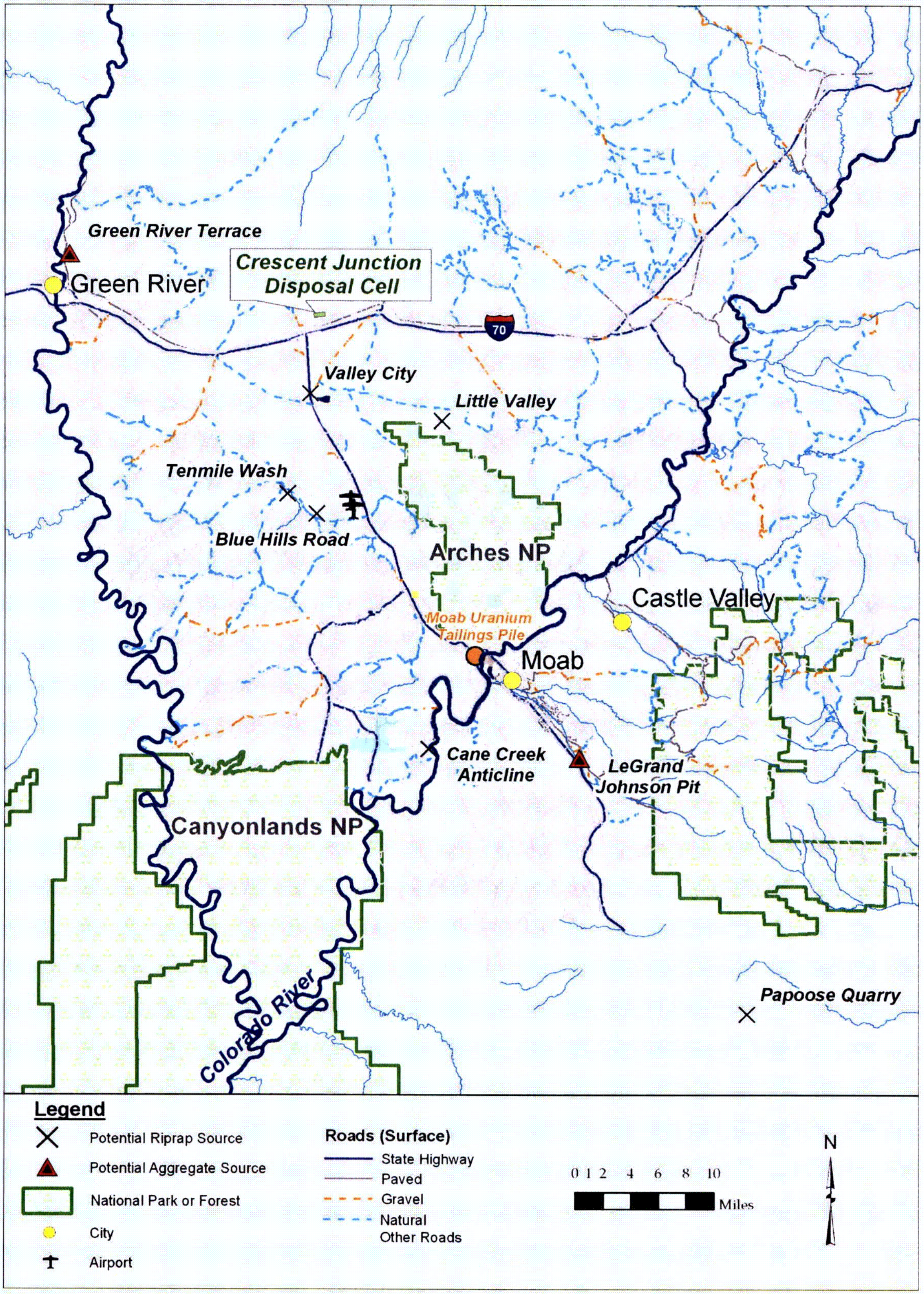


Figure 6–8. Potential Rock Source Location Map

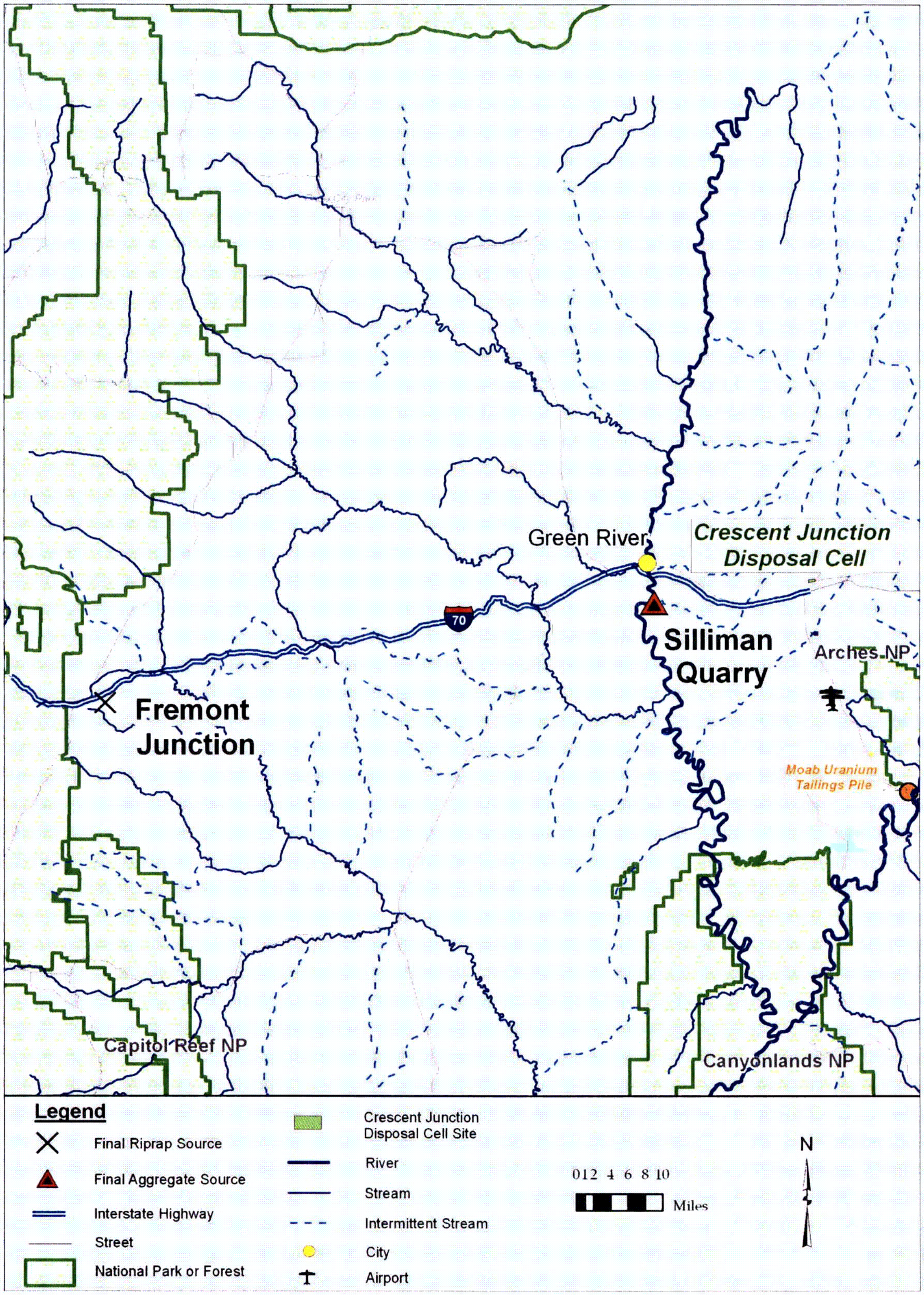


Figure 6–9. Final Rock Source Location Map

The volume of rock required for Area C (Figure 6-10) of the cell is 2,683,296 ft^3 (99,381 yd^3). Conservatively assuming a 15 foot thickness for the Silliman deposit, the total estimated volume of material in the lower terrace is 19,602,000 ft^3. Assuming only rock four inches or greater would be crushed for use on the cell cover, and using a volume percentage of 15 percent for four inches or greater material, the total volume is reduced to 2,940,300 ft^3. Further reducing the volume to eliminate the percentage of tan, friable, sandstone (15 percent) results in a total volume of 2,499,255 ft^3 for the lower terrace. Using these assumptions, some portion of material from the middle terrace would need to be quarried to meet the cell Area C volume requirements.

Testing for NRC quality criteria has already been conducted for the basalt deposits at the Fremont Junction site. The NRC score for this material was 83.7 percent, indicating no oversizing would be required for use as riprap. Therefore, only a qualitative evaluation of the deposit was recently conducted to determine the consistency of the basalt characteristics across the site, evaluate the amount of overburden at various locations across the site, and estimate the volume of the deposit to ensure the quantity of rock is sufficient for the cell requirements.

The deposit at Fremont Junction is an alluvial deposit, approximately 20-plus feet thick overlying a pediment of Late Cretaceous shale bedrock from the Blue Gate Member. The deposit contains a significant volume of rounded, vesicular, tholeiitic basalt boulders, parts of which have previously been used to cap portions of the Green River UMTRA disposal cell. The evaluation of the deposit at Fremont Junction indicated that the lithology of the basalt boulders was relatively uniform at all excavation pits. Sediment overburden across the site varies, with a two to four feet thick caliche layer present in two of the pits just below the surface, above the basalt deposit.

The thickness of the overburden above the basalt deposit ranged from approximately one to five feet. Based on the excavation pits and communications with personnel who lease part of the site, the deposit is variable laterally with regards to the quantity of basalt boulders. Previous quarrying at the site has followed "channels" where the number of boulders was greater, this would likely be repeated if this quarry is used as the riprap source for Crescent Junction. The current area of the Fremont Junction deposit that would likely be used is 400 acres.

The volume of riprap required for cell Areas A and B (Figure 6-10) is 1,685,046 ft^3 (62,409 yd^3). The volume of basalt boulders in the deposit varied significantly in the four excavations and is roughly estimated to be between 15-45 percent. Conservatively assuming a thickness of 10 feet for the deposits and 20 percent basalt boulders, the total volume of usable basalt is over 34,000,000 ft^3. Therefore, the volume of rock at the site is more than adequate for the Crescent Junction cell requirements.

Based on the site selection criteria noted above, the rock quarry at the Silliman site has been preliminarily selected as the source location for the cell cover aggregate. Final determination of the aggregate source location will be made after test results from the Silliman site have been reviewed. These test results and possibly additional volume calculations based on them will be submitted in an addendum to the RAP. For the riprap source for cell Areas A and B, the basalt deposit at Fremont Junction has been preliminarily selected. While the distance to the disposal cell (40 miles) is significant, the selection of this deposit ensures a quality source of rock for the critical areas of the cell. Areas closer to the disposal cell likely to have deposits of durable rock may be investigated as alternate rock sources prior to initiation of the rock emplacement at the disposal cell.

Table 6–14. Silliman Site Rock Size and Lithologic Evaluation

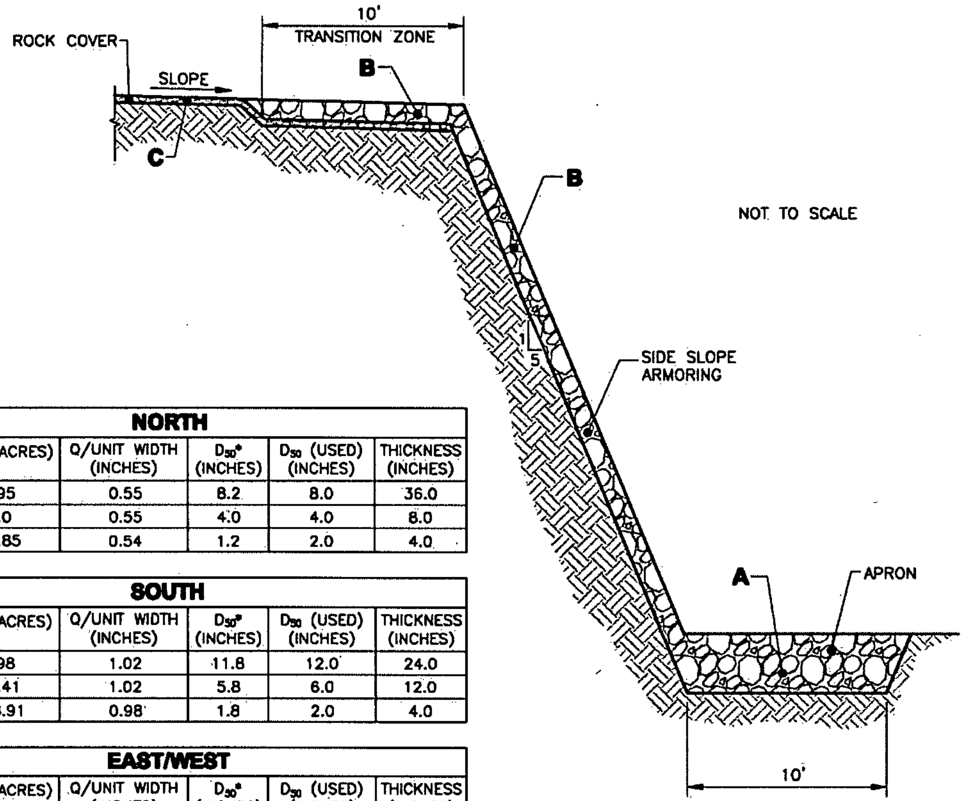
Rock Size Evaluation

Sediment to 2" (%)	2" to 4" (%)	Greater than 4" (%)
45	30-35	20-25
Note: Sandy sediment estimated at 15-20% of total volume. The largest observed clast was approximately 11 inches.		

Lithologic Evaluation

Lithologies (Greater than 4")	Quartz Veins, Cherty Masses (%)	Tan, Fine to Medium-Grained Friable Sandstone (%)	Tan Sandstone (%)	Reddish Sandstone (%)	Gray, Aphanitic, Siliceous Limestone (%)	Dark Gray Quartzite (%)	Misc
	5	10-15	15-20	35-40	10-15	5	5

Lithologies (2" - 4")	Quartz Veins, Cherty Masses (%)	Tan, Fine to Medium-grained Friable Sandstone (%)	Tan Sandstone (%)	Reddish Sandstone (%)	Gray, Aphanitic, Siliceous Limestone (%)	Dark Gray Quartzite (%)	Gray-Green Olive Cemented Sandstone
	5	20-25	25	30-35	10-15	<5	<3



NORTH					
	AREA (ACRES)	Q/UNIT WIDTH (INCHES)	D_{50}* (INCHES)	D_{50} (USED) (INCHES)	THICKNESS (INCHES)
A	1.95	0.55	8.2	8.0	36.0
B	7.0	0.55	4.0	4.0	8.0
C	55.85	0.54	1.2	2.0	4.0

SOUTH					
	AREA (ACRES)	Q/UNIT WIDTH (INCHES)	D_{50}* (INCHES)	D_{50} (USED) (INCHES)	THICKNESS (INCHES)
A	0.98	1.02	11.8	12.0	24.0
B	16.41	1.02	5.8	6.0	12.0
C	128.91	0.98	1.8	2.0	4.0

EAST/WEST					
	AREA (ACRES)	Q/UNIT WIDTH (INCHES)	D_{50}* (INCHES)	D_{50} (USED) (INCHES)	THICKNESS (INCHES)
A	1.08	0.2	4.7	6.0	18.0
B	13.63	0.2	2.3	4.0	8.0
C	NA	NA	NA	NA	NA

*CALCULATED VALUE

FINAL COVER

	VOLUME (YD^3)	VOLUME (MILLION YD^3)
RRM	11200000	11.2
INTERIM COVER	298144	0.298
RADON BARRIER	1192576	1.193
INFILTRATION BARRIER	149072	0.149
FROST PROTECTION LAYER	894432	0.894

	VOLUME (FT^3) D_{50} 12 IN	VOLUME (FT^3) D_{50} 8 IN	VOLUME (FT^3) D_{50} 6 IN	VOLUME (FT^3) D_{50} 4 IN	VOLUME (FT^3) D_{50} 2 IN
TOTAL VOLUME A	130680	169884	71874		
TOTAL VOLUME B			714384	598224	
TOTAL VOLUME C					2683296
TOTAL (FT^3)	130680	169884	786258	598224	2683296
TOTAL (TON)	6077	7900	36561	27817	156973

Figure 6–10. Riprap Requirements for Disposal Cell Top Cover, Side Slopes, and Apron

End of current text

7.0 Disposal Cell Design and Construction Details

This section summarizes the disposal cell design, based on information presented in Sections 4.0, 5.0, and 6.0 of the RAS. Design features and considerations relevant to compliance with EPA regulations include the following:

- Geotechnical stability – consideration of factors including site stratigraphy, and evaluation of performance for slope stability, settlement, and liquefaction (Section 4).
- Radon attenuation – evaluation of the disposal cell cover for acceptable radon emanation under long-term conditions. The typical UMTRA Project cover design will be used (Section 5).
- Surface water hydrology and erosion protection – acceptable performance was evaluated under long-term conditions (represented by using the PMP) (Section 6).

Section 8.0 discusses the relevant cell design criteria with respect to ground water protection.

7.1 Disposal Cell Design

Figure 7–1 shows the disposal cell footprint and existing and proposed site features. Typical cross sections through the disposal cell are shown in Figures 7–2 and 7–3. The disposal cell will cover approximately 230 acres, and will be constructed partially below grade. The anticipated depth of excavation will vary between 10 to 20 feet below grade. The northern edge of the disposal cell will be excavated into the existing grade with only the cover being above existing grade. The southern edge of the disposal cell will be excavated to approximately 20 feet below the existing grade. There will be a berm of approximately 20 feet in height along the southern edge of the disposal cell. A berm along the east and west edges of the disposal cell will vary in height from 0 to 25 feet above the existing grade. The top surface of the disposal cell will slope upward from the north to approximately the quarter point and then slope down to the southern edge. The side slopes of the disposal cell are designed with maximum slopes of 5:1 (20 percent).

The current design volume of the cell is estimated at 11.15 million yd^3. This accounts for RRM from the tailings pile, subpile, and contaminated soils on the processing site and vicinity properties, which primarily surround the processing site.

The area of the cell and depth of excavation have been calculated to accommodate the RRM volume, such that sufficient materials generated from cell excavation are used for embankment and cover material. The volume of material to be excavated within the footprint of the cell is 3.19 million yd^3 of colluvial material and 3.46 million yd^3 of weathered Mancos Shale. The embankments require 0.46 million yd^3 of fill while the cover design requires 2.26 million yd^3 of fill. There will be 3.84 million yd^3 of excess material. Excess material will be placed to the north between the cell and the Book Cliffs to divert surface water away from the cell. A ditch will be constructed between the excess material placement and the cell to divert surface water that accumulates there to the east and west away from the cell.

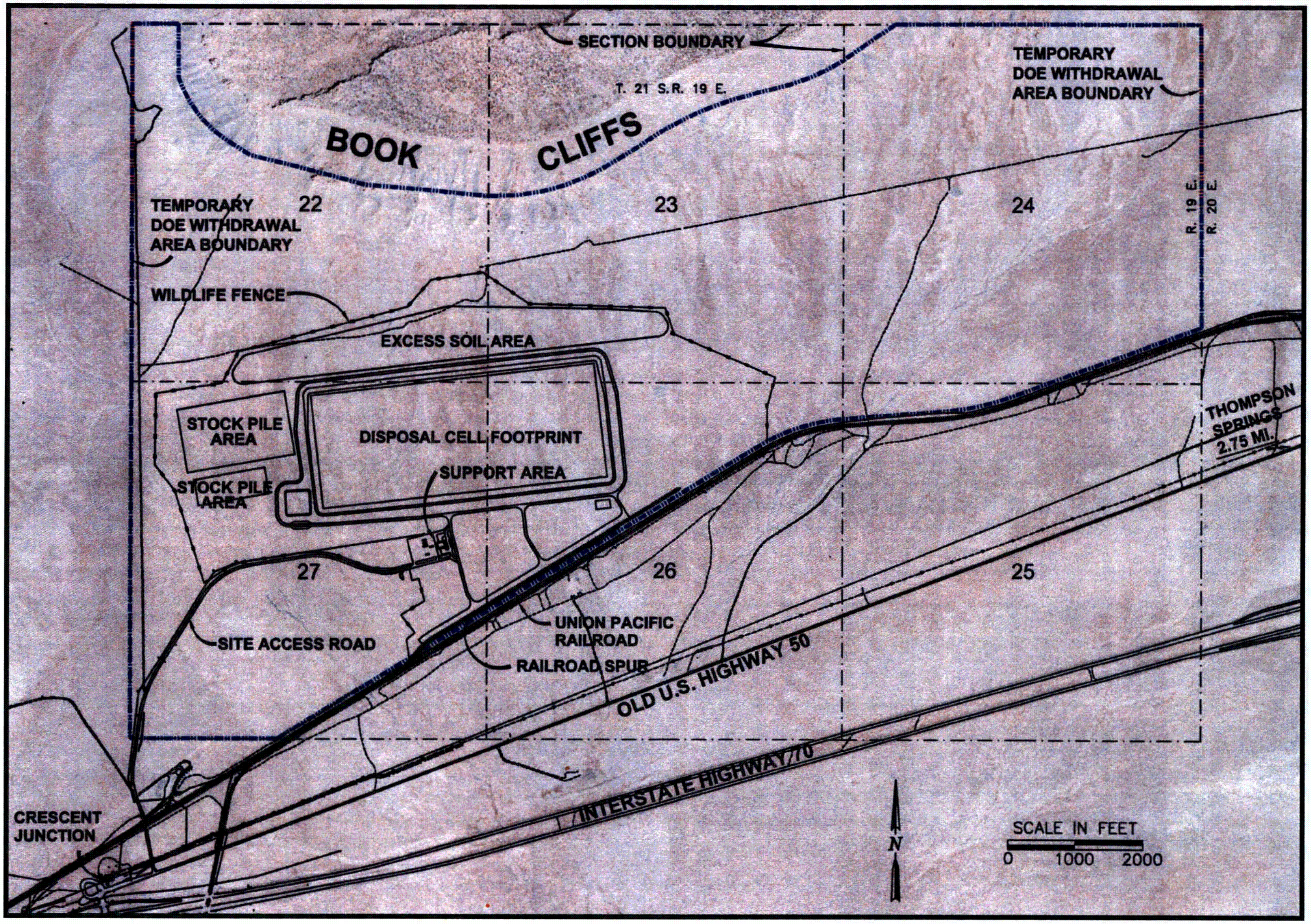


Figure 7–1. Crescent Junction Disposal Cell Footprint and Existing and Proposed Site Features

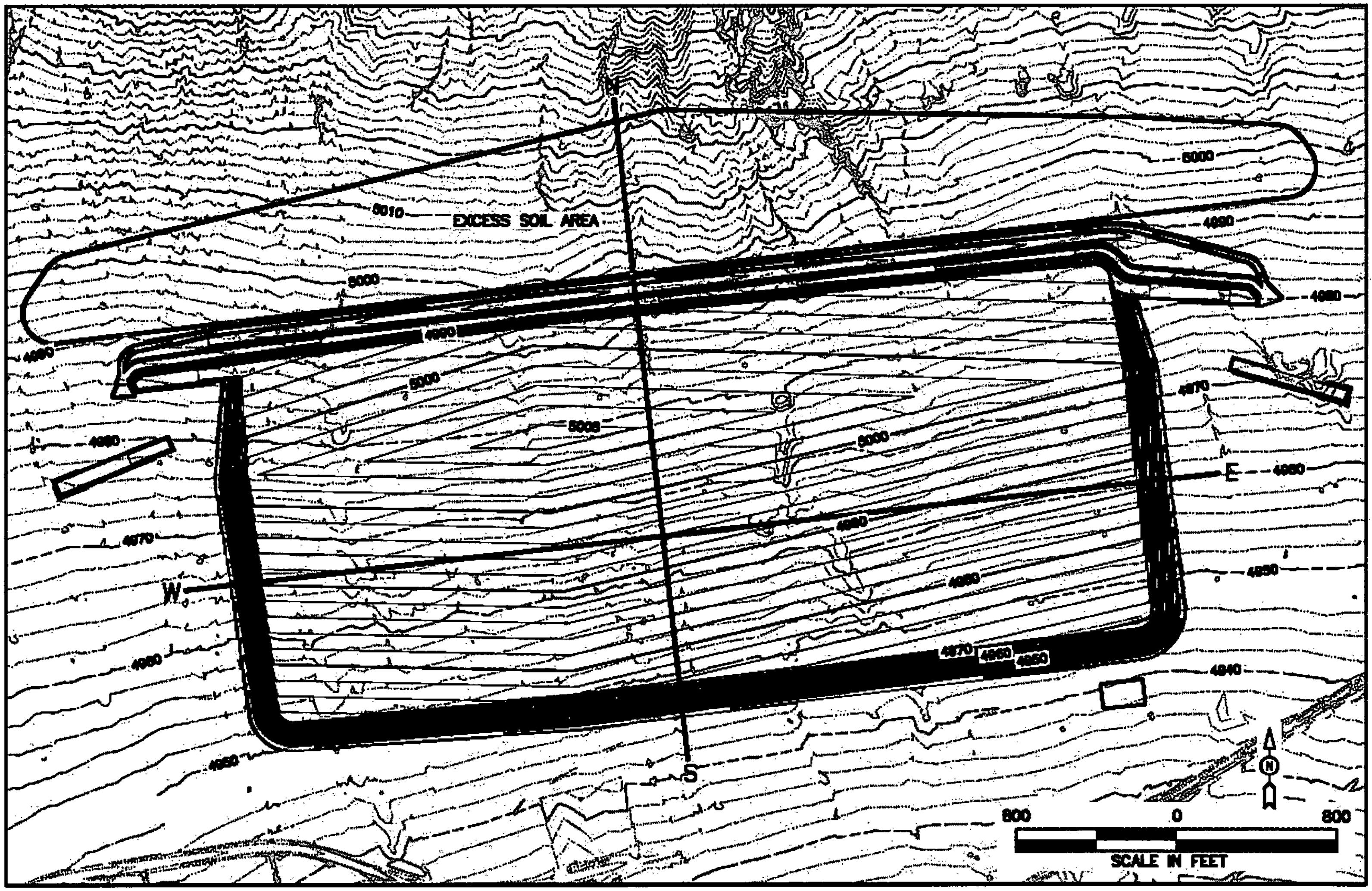


Figure 7–2. Disposal Cell Layout with Typical Cross-Section Locations

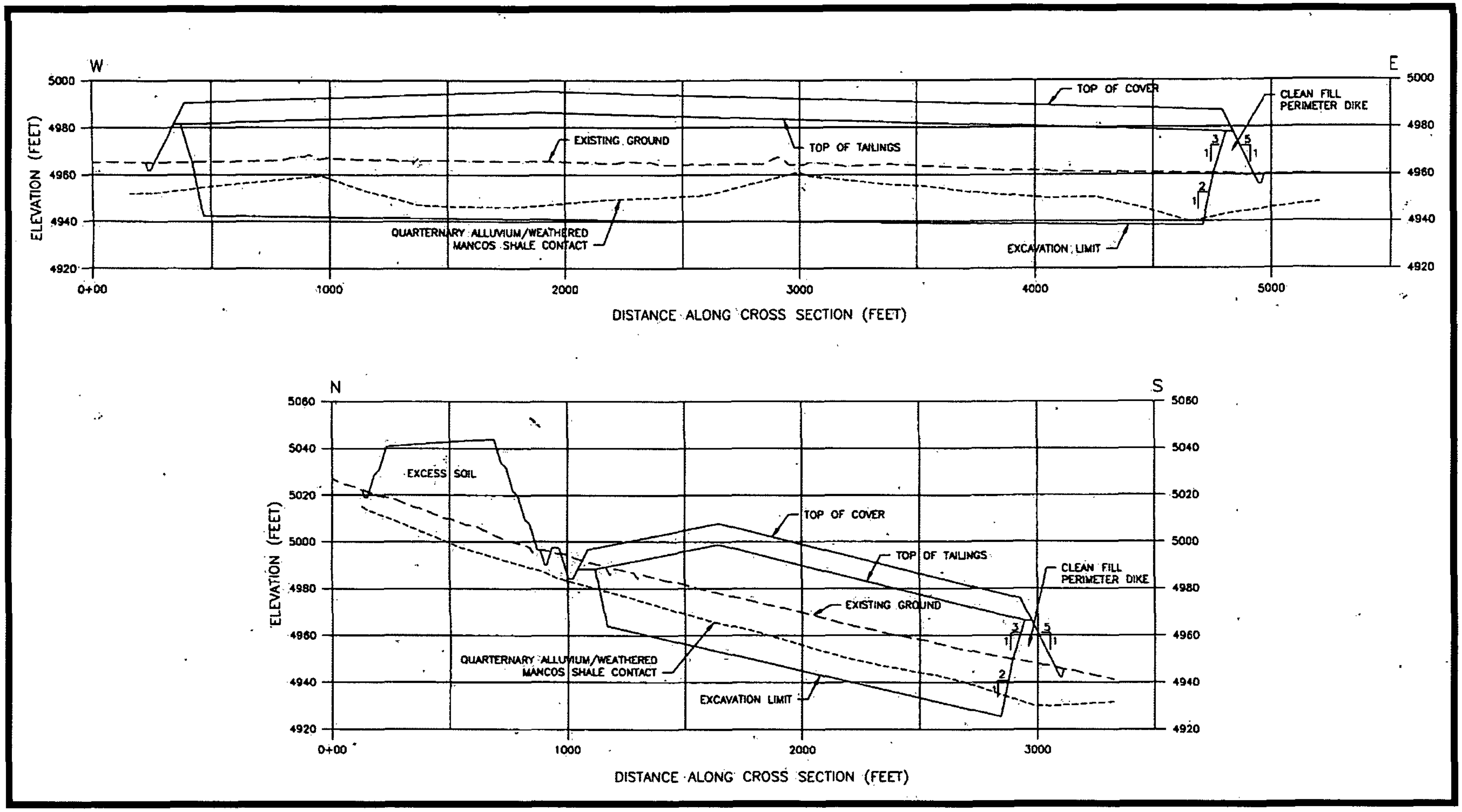


Figure 7–3. Typical Cross Sections for Crescent Junction Disposal Cell

The UMTRA Project cover design will be used. This design will include components to reduce radon emanation from the RRM, reduce infiltration of meteoric water into the RRM, prevent freeze thaw cycles from affecting the cover, prevent gullies and rills from eroding into the radon barrier layer, and prevent biointrusion into the RRM. The disposal cell cover will be less permeable than the materials underlying the cell, which will prevent "bathtubbing" of water in the bottom of the cell. A series of standpipes will be constructed through the cover to the bottom of the cell for water removal. Perimeter berms are incorporated into the design to minimize lateral water migration.

The radon barrier is discussed in detail in Section 5.0 and the rock armoring is discussed in detail in Section 6.4.

The infiltration and biointrusion barrier over the radon barrier of the cover has three basic functions. It provides positive drainage of any surface water that seeps through the upper layers of the cover to the out slopes of the cover, it provides a barrier against burrowing animals, and it provides a break in the soil regime to discourage root growth into the radon barrier. However, in the event that native upland plants are not established and deeper-rooted plants, such as greasewood occupy the site, increased maintenance may be required to remove these deep-rooted plants so they do not root into the radon barrier and provide pathways for water to infiltrate into the RRM.

The frost protection layer provides a sacrificial layer over the radon barrier to ensure the freeze/thaw cycle of the site will not adversely affect the radon barrier. Addendum D, Calculation C-13 is check of the freeze/thaw depth. This calculation estimates the freeze/thaw depth to be 43 inches for a recurrence interval of 200 years. Therefore, the thickness of the rock armoring, frost protection and biointrusion layers of four feet should ensure the freeze/thaw cycle does not affect the radon barrier.

A schematic depiction of the disposal cell in relationship to surrounding geologic and hydrogeologic features is shown in Figure 7–4. As discussed in Section 8.0, the cell construction and site hydrogeology is anticipated to effectively isolate the RRM from the uppermost Dakota aquifer. The stable geologic, seismic, and geomorphic setting of the site will ensure adequate control of the RRM for the design life of the cell. Details of the disposal cell design can be found in Addendums B and C. Calculations for the disposal cell are in Addendum D.

7.2 Construction Details

7.2.1 Phased Construction

The construction of the disposal cell will be performed in stages in order to prevent excessive areas of the cell from remaining open while waiting arrival of the shipments of contaminated material. The phased construction also minimizes the amount of contaminated material exposed in the disposal cell. Construction of the first phase of the disposal cell will commence on the western side of the cell and progress towards the east. The area of this first construction effort is roughly 2,000 feet in the north-south direction and 1,000 feet in the west-east direction (Figure 7–5). Subsequent phases of cell construction will continue eastward.

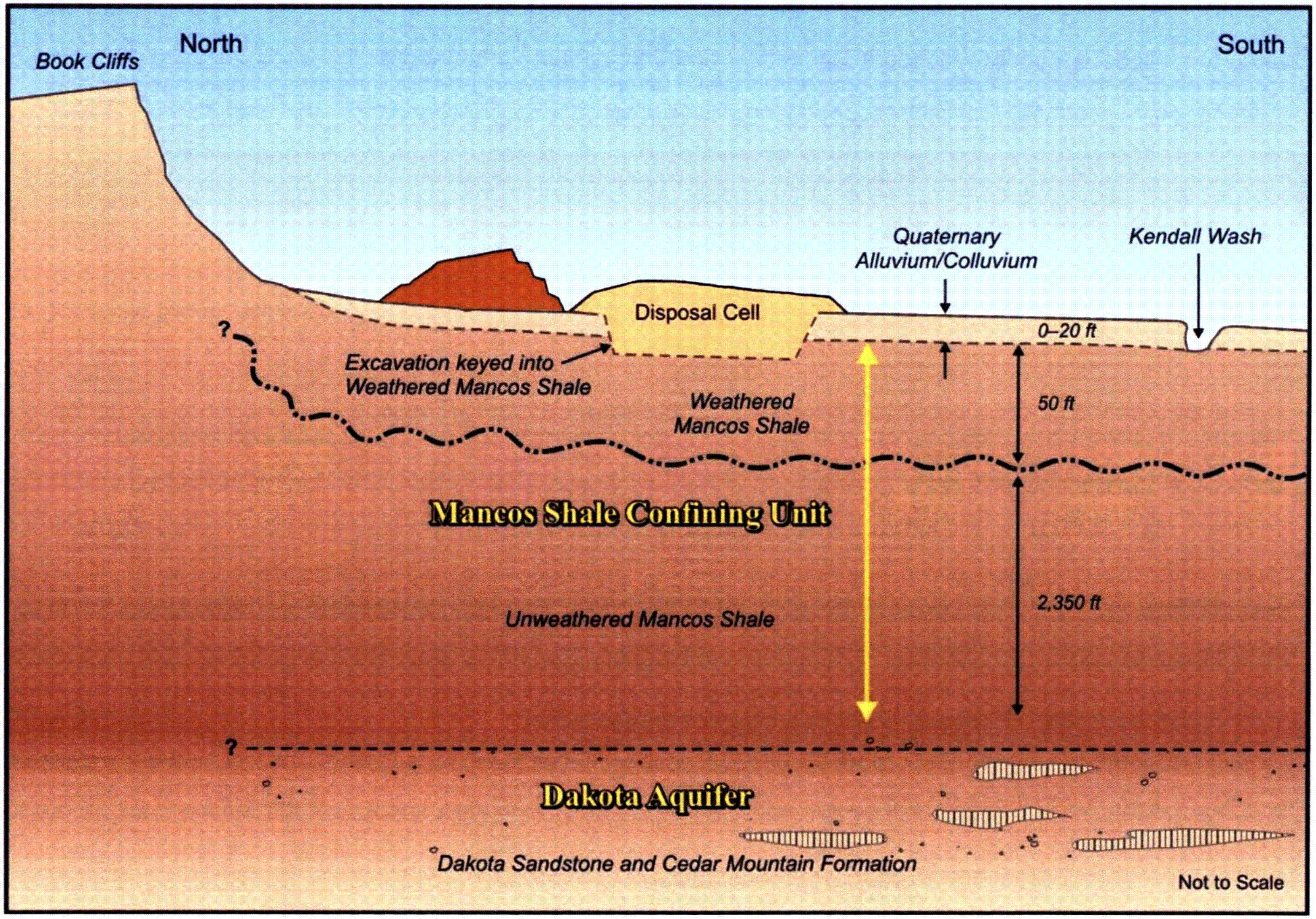


Figure 7–4. Schematic Diagram of Crescent Junction Disposal Cell and Surrounding Geologic and Hydrogeologic Features

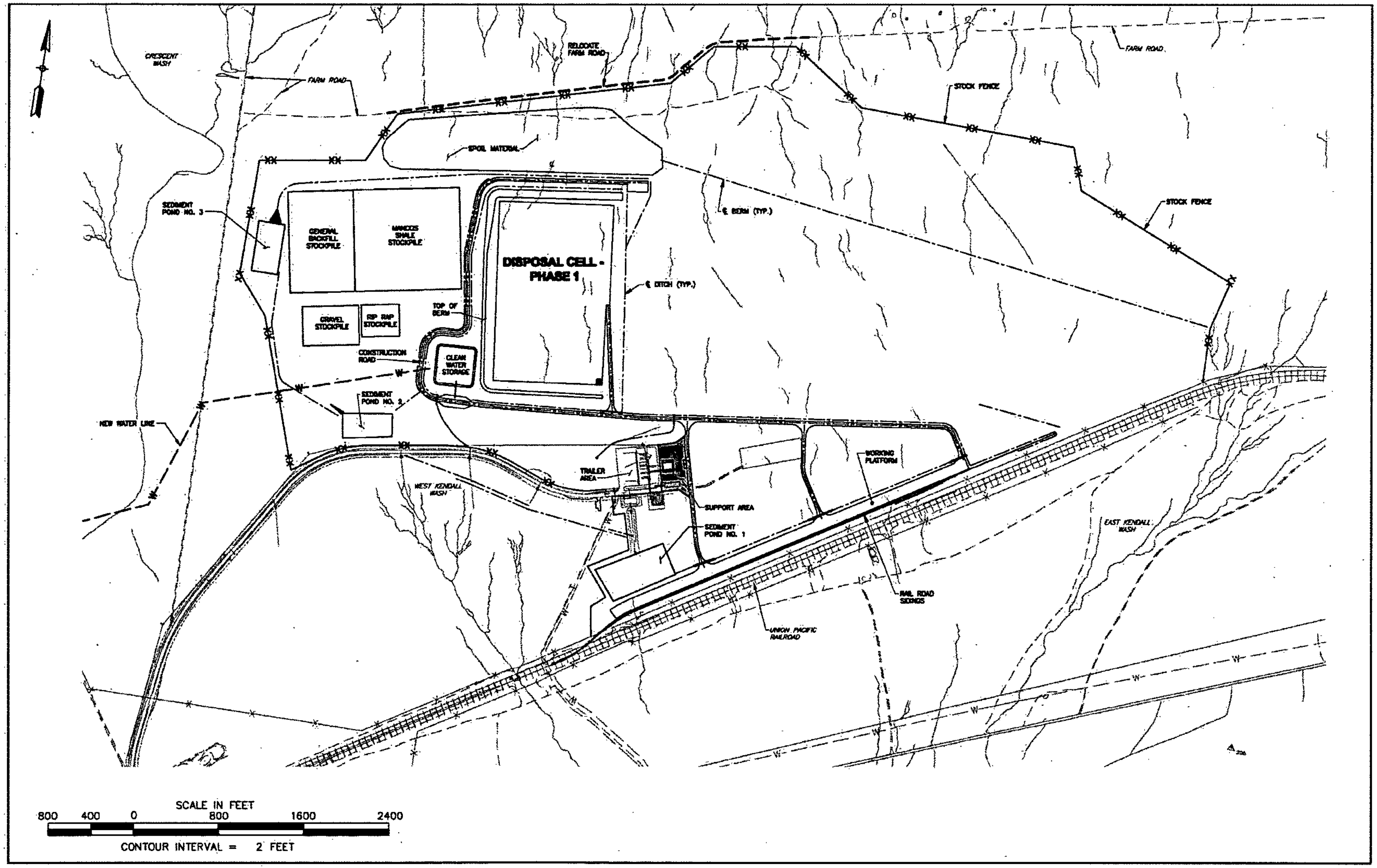


Figure 7–5. Phase 1 of Disposal Cell Construction

The eastern edge of the disposal cell is considered to be the flexible component of the cell. In the event that a larger volume of contaminated material is encountered at or under the Moab tailings pile, the eastern edge of the cell could move further to the east to accommodate the extra material. Current projections include two feet of contaminated soil below the tailings pile. If the volume is less than estimated, the cell's eastern wall could be moved to the west and thus shorten the length of the cell. Determination of this volume will be better estimated as the excavation at the tailings pile extends into the contaminated sub-pile material.

Initial Crescent Junction Site construction will include installation of infrastructure components such as the construction of a water pipeline from the Green River, 21 miles to the west of the site, a storage pond for construction water roads; and support facilities, including the transfer yard where containers from the Moab Site will be off-loaded onto trucks.

7.2.2 Cell Excavation

Excavation of the disposal cell will include segregation of the various materials encountered into stockpiles for future cover component use as well as for general backfill and construction of the protective wedge on the north side of the cell. The surface layer will be removed and placed into a 'topsoil' stockpile for future restoration purposes. The alluvial soils and Mancos Shale will be used in the construction of the outer berms of the cell. The weathered Mancos Shale also will be conditioned and stockpiled for future use as the radon barrier layer of the cell cover. Excess soil will be used to construct the protective wedge to the north of the cell.

The excavation will extend to a maximum depth of roughly 20 feet in the footprint of the cell. Per the design drawings in Addendum C, the excavation will be a minimum of two feet into the Mancos Shale. If there are small areas or pockets where Mancos Shale is not encountered at the specified drawing location for the cell bottom, the non-Mancos material will be undercut two feet and replaced with Mancos Shale. Equipment used for the excavation will include scrapers, excavators, and dozers for ripping the Mancos where needed.

Along the eastern edge of Phase 1, an interim berm will be installed to separate the RRM placement area from the adjacent uncontaminated zone.

For the first phase, once the excavation is complete and the western portion of the cell berm is built, the construction will transition to placement of the RRM from the Moab Site. If warranted by schedule needs, excavation and placement sequencing can be performed concurrently as long as measures are taken to prevent cross-contamination. Interim berms may be placed to segregate the "clean" construction from the RRM placement activities.

7.2.3 Placement of Contaminated Materials in Disposal Cell

RRM to be placed in the disposal cell include mill tailings, interim cover soils, starter embankment soils, contaminated subsoils beneath the tailings, vicinity property materials, and mill debris. All of these materials are from the Moab uranium mill.

The primary RRM materials are the mill tailings generated from operation of the Moab Processing Site. The tailings were generated as a residue from milling operations for recovery of uranium. The tailings (sand to silt-sized materials) were discharged as slurry into an impoundment constructed and operated adjacent to the Moab mill. The impoundment was operated as a side-hill structure, with an earthen starter embankment constructed on the downhill side. Tailings were contained within the impoundment by a perimeter embankment constructed with tailings, and raised in stages in an upstream manner (Vick 1990). The tailings slurry was discharged along the perimeter embankment by spigotting, resulting in the coarse fraction of tailings (tailings sands) settling out along the perimeter, and the fine fraction of tailings (tailings slimes) settling out in the interior of the impoundment. The tailings have been classified for characterization and excavation as tailings sands (primarily sand-sized material), tailings slimes (primarily silt-sized material), and transitional material (a mixture of silts and sands). The shear strength and handling properties of the tailings vary with material type, from the sands (with a water content by dry weight of approximately 10 percent) to the slimes (with a water content by dry weight of over 100 percent).

The remaining materials to be placed in the disposal cell consist of soils and debris. The soils are primarily alluvial materials (sand to boulder-sized material) that were used for starter embankment material and interim cover material, and comprise the subsoils beneath the impoundment. Debris that was buried in the impoundment includes (1) structural debris, tanks, pressure vessels, and other material from demolition of the Moab mill; (2) pipe and supporting trestle material from operation of the tailings impoundment; and (3) wick drain material from recent tailings dewatering operations.

All of the contaminated material will be excavated at the Moab Site, placed in tight containers, and transported from Moab to Crescent Junction. The containers will be off-loaded onto six-wheel drive, off-road articulated trucks. A ramp into the cell will allow for the loaded containers to be end dumped over jersey barriers into the southwestern portion of the cell footprint. Dozers, using the global positioning system (GPS) integrated computer aided earthmoving system (CAES) system, will then spread and compact the material in lifts per the specifications. Quality control personnel will perform required testing and verification per the Remedial Action Inspection Plan (RAIP) in Addendum E. Placement will commence in the southwest corner of the cell floor, proceed north, and then work east.

The objective of material placement in the disposal cell will be to minimize subsequent settlement by compacting compressible materials and filling void spaces within and around incompressible materials (e.g., debris). The first phase of the excavation and placement of contaminated materials will have minimal debris. Specifications for RRM placement are found in Addendum B, 31-00-20 R1.

7.2.4 Transient Drainage

Although the tailings will be dried to near–optimum moisture conditions prior to being placed in the disposal cell, the average moisture content of the tailings will probably be biased on the wet side of optimum, leaving enough residual moisture to drain from the RRM under the influence of gravity. Furthermore, post-construction consolidation of the RRM will release water as the consolidation proceeds. These two components of released water constitute what is called transient drainage.

As the first phase of construction and placement proceeds, any released water will be collected in a sump at the southeastern most region of the bottom of the cell. The accumulated water can be used for dust control for the construction activities. Subsequent phases of excavation, construction, and RRM placement will likewise capture water in sumps. As a segment of the cell is completed, transient drainage will be monitored with the installation of standpipes tapping into sumps positioned at four locations at the interior south edge of the disposal cell (Figures 7–6 and 7–7).

In the event that transient drainage accumulates in a sump and reaches some action level, DOE will pump the fluid out through a standpipe. After the disposal cell is constructed, and no further water accumulates in the sump, DOE will remove the standpipes or abandon them in place.

7.2.5 Placement of Cover

An interim cover will be placed on the tailings where the full height of placement has been achieved. This cover material will be placed with a dozer equipped with the CAES system and a smooth drum vibratory roller. The equipment will push the interim cover material ahead of it so that the equipment will not become contaminated nor cross-contaminate the interim cover layer. This interim layer is uncontaminated and acts as a sacrificial layer that protects the RRM from erosion by wind and water and also minimizes worker exposure.

The subsequent layers of the cover will be placed on top of the interim cover. The radon barrier will be installed in lifts per the specifications listed in Addendum B. Equipment that will be used for this layer includes scrapers, compactors, and dozers equipped with GPS. After a segment of the radon barrier is approved, the next layer will be installed. The gravel for the infiltration and biointrusion barrier layer will be installed using belly dump trucks and dozers. The frost protection, and rock, or riprap final cover layers will all be placed similarly with belly dump trucks and dozers.

The transition from the top cover to the side slopes is shown in Figure 7-8. Precipitation off of the top slope will flow through a 10 foot "apron" of larger rock onto the side slope erosion protection riprap. The underlying layers of the cell cover will interconnect to the side slopes at the same angle as the top slope, which will drain precipitation that infiltrates into the cover layers. The infiltration layer is much more permeable and will serve to drain excess infiltrated water to the outside slope.

7.3 Testing and Inspection

The RAIP provides details of the methods, procedures, and frequencies by which construction materials and activities are to be tested and inspected to verify compliance with the design specifications. Quality assurance requirements will be in accordance with the RAIP, the Quality Assurance Program Plan, and the approved design specification requirements. Addendum E contains the RAIP.

Placement of the tailings into the disposal cell will be monitored using a system called CAES. The system can be used to monitor compaction efforts and slope placement in real time using a differential GPS-based method that provides continuous logs of disposal operations. CAES has been successfully used in various waste disposal sites such as the Clive Facility in Utah, since

June 2005; the White Street Landfill, in Greensboro, North Carolina, for the past 2 years; the Sprint Landfill, Fort Bend County, Texas, since January 2004; and the Olinda-Alpha Landfill, County of Orange, California.

7.4 Construction Sequence

Excavation of the first phase of the Crescent Junction disposal cell and construction of the clean-fill berms will begin in 2008. RRM placement is currently scheduled to commence in the spring of 2009 and an interim cover will be placed on RRM sections as they reach final designed height. Final cap placement on Phase 1 is currently scheduled for 2012. Subsequent construction phases have been forecast to culminate in cell completion in early FY 2026. Funding and other government rulings may impact the overall schedule.

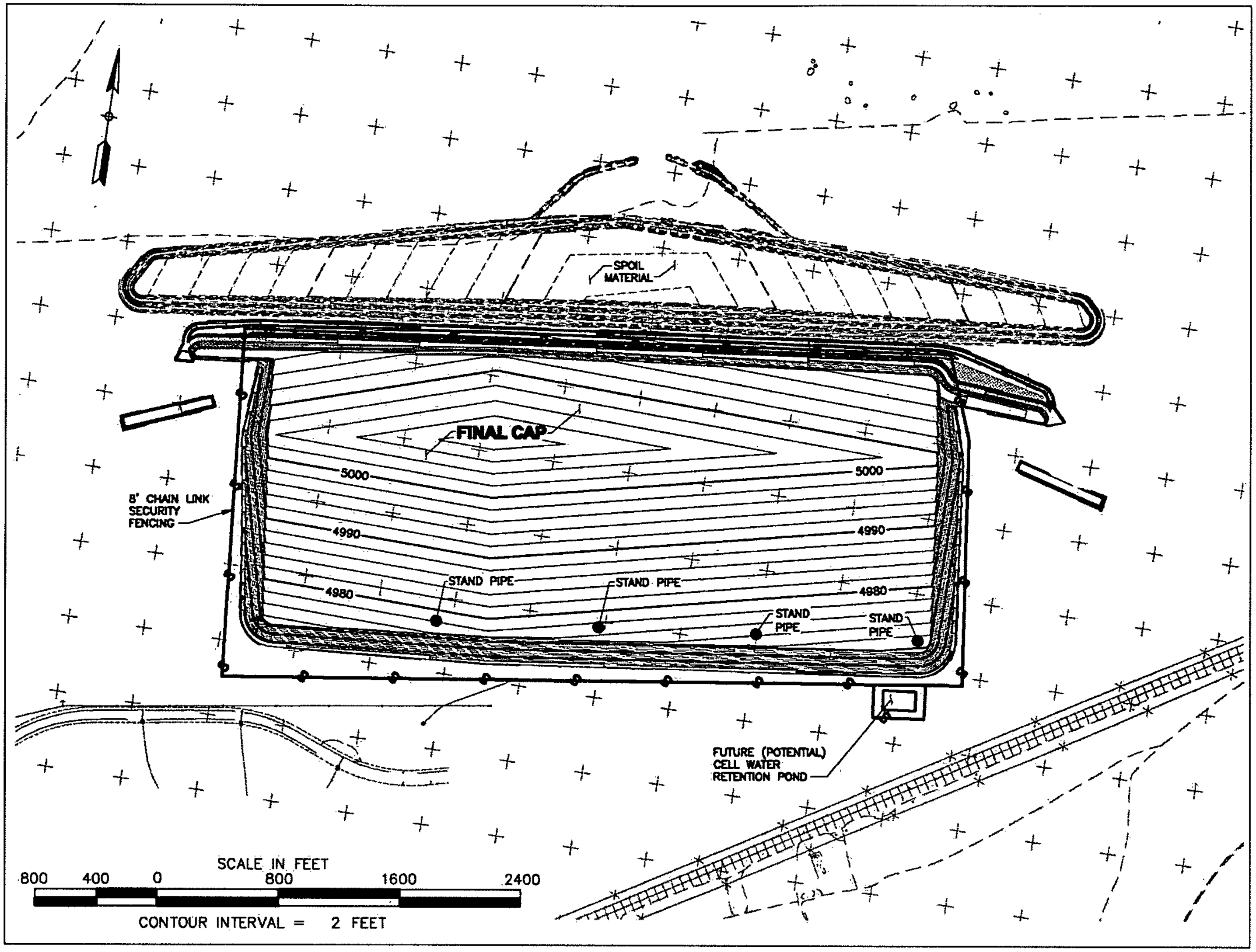


Figure 7–6. Location of Stand Pipes in the Disposal Cell

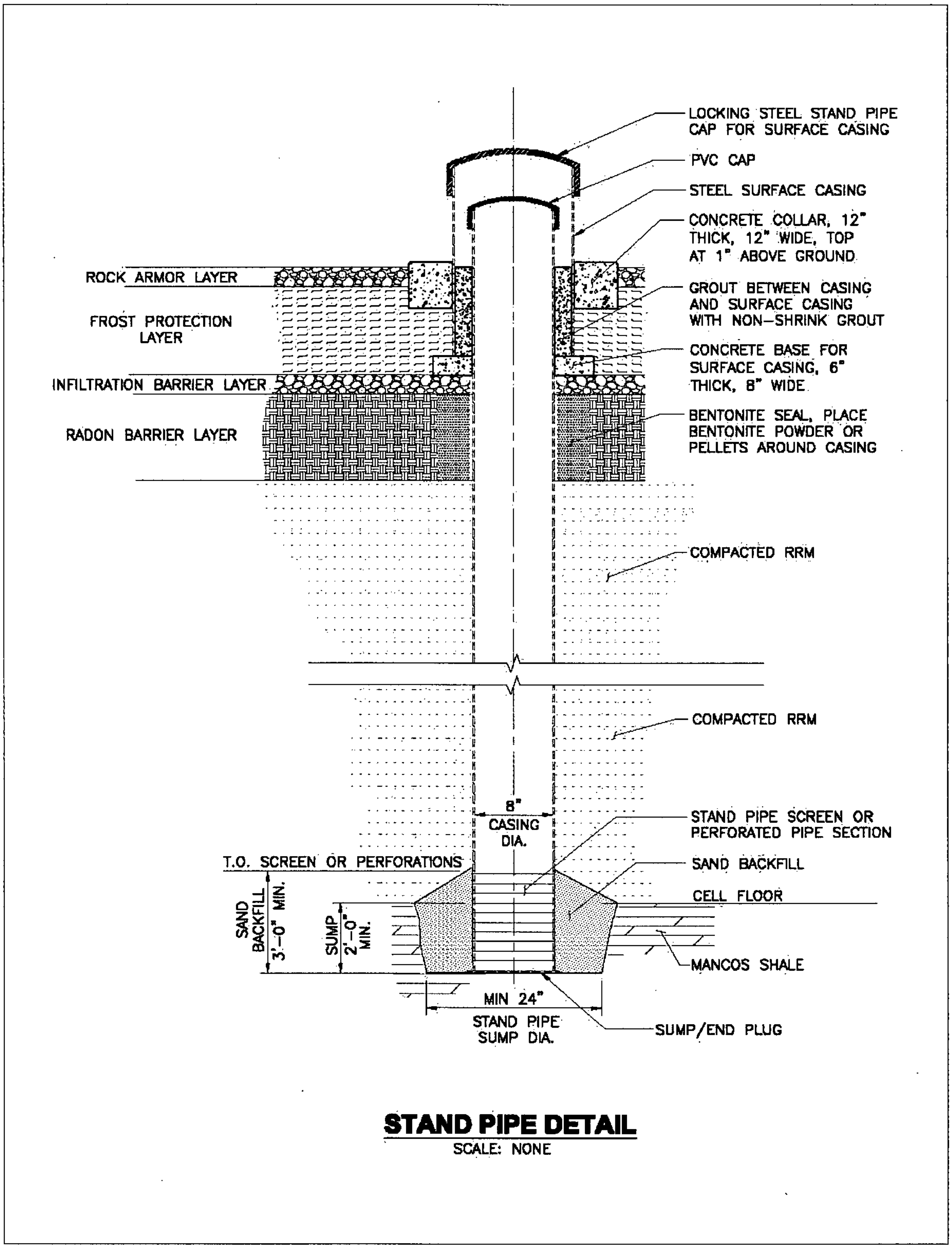


Figure 7–7. Details of Stand Pipe

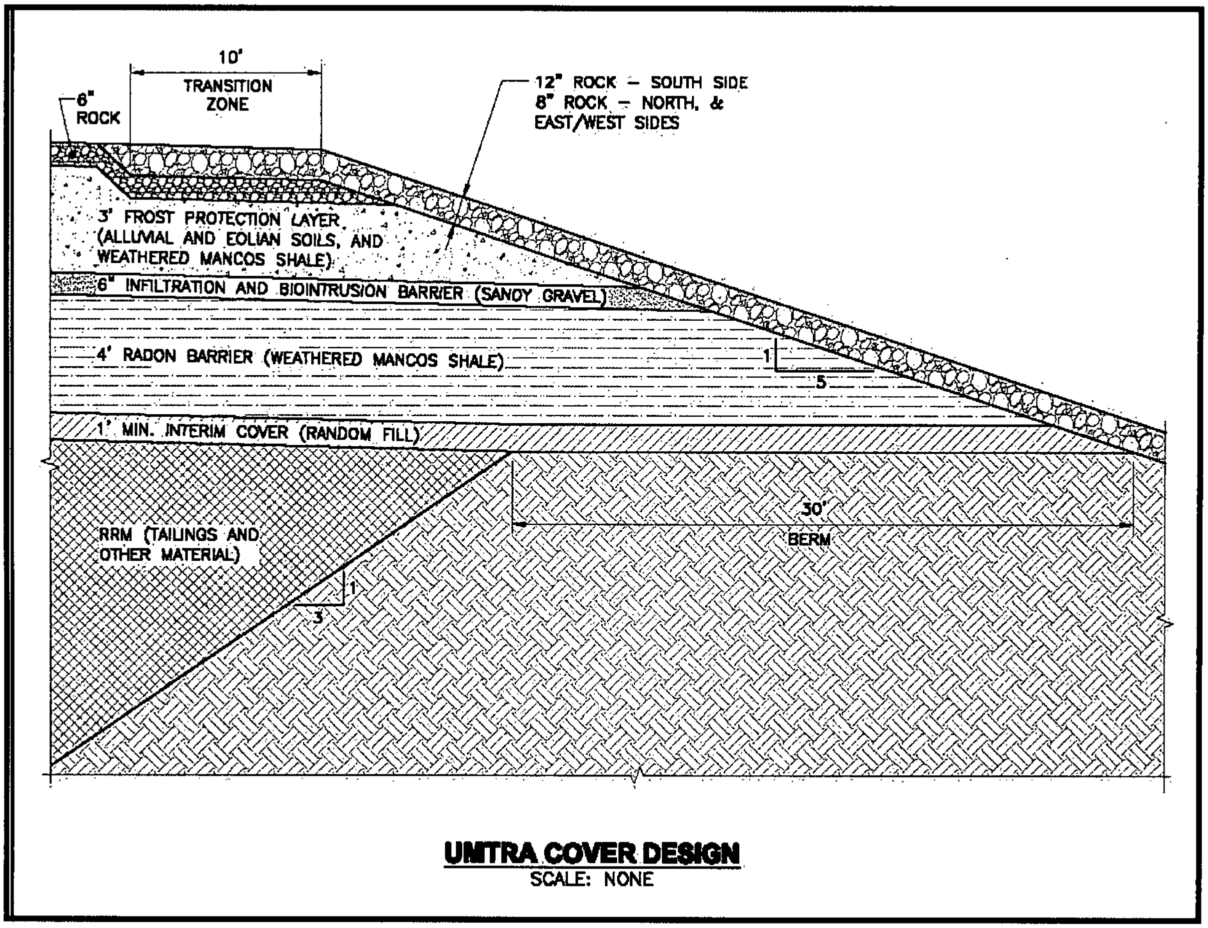


Figure 7–8. Transition of Disposal Cell Top Cover to Side Slopes

8.0 Water Resources Protection

This section presents the water resources protection strategy for the Crescent Junction disposal cell. Many key features and characteristics presented and described previously in this document have led to the selection of hydrogeologic isolation as the appropriate means of ensuring protection of ground water beneath the disposal cell. The effectiveness of hydrogeologic isolation precludes the need for a ground water monitoring and corrective action program for the site and ensures that ground water in the uppermost aquifer will remain isolated from any cell-derived water during the design life of the disposal cell.

DOE has characterized the hydrogeologic units, hydraulic and transport properties, geochemical conditions, and water use at the Crescent Junction Disposal Site. Major points are summarized below. Details of hydrogeologic characterization are provided in Section 3.0 of this document and Attachment 3 of the RAP. Additional information supporting the water resources protection strategy is provided in Attachment 4 of the RAP.

8.1 Summary of Key Hydrogeologic Site Features

The Crescent Junction Disposal Site is located in an area with a very arid desert climate. The site receives an average of 9.1 inches of annual precipitation; pan evaporation rates are 60 inches per year. Precipitation events tend to be brief and intense, followed by rapid evaporation. Test pits excavated during field investigations at the site showed no visible evidence of saturation.

The bedrock beneath the disposal site is Mancos Shale, which is an important regional confining unit composed primarily of mudstones having a very low hydraulic conductivity. Highly to slightly weathered Mancos Shale in a layer 20 feet to 100 feet thick overlies the much thicker unweathered Mancos Shale. About 2,400 feet of confining Mancos Shale separates the uppermost Dakota aquifer from the ground surface.

Vertical travel times for ground water to migrate from the surface to the uppermost aquifer have been estimated at 3,330 to 33,300 years, far exceeding the 1,000-year maximum design life for the disposal cell. In addition, modeling of geochemical processes that are likely to occur as ground water moves through the subsurface indicates that attenuation of ammonia, and to a lesser degree uranium, would probably lengthen the break-through times for these constituents.

There are no known ground water discharge points within one mile to two miles of the site. Some local water users obtain water from springs located seven mile upgradient of Thompson Springs, Utah; the source of these springs is in the Mesaverde Group, which is stratigraphically above the bedrock units at the disposal site. There is no use of the limited water occurring in the Mancos Shale in the vicinity of the disposal site. Ground water is pumped from wells ranging from 800 feet to 1,200 feet deep near Canyonlands Field (Grand County Airport), which is 15 miles south of the disposal site. The nearest major source of surface water is the Green River, 20 miles west of the disposal site. Geologic and hydrologic features of the disposal site are discussed in greater detail in Attachments 2, 3, and 4.

8.2 Summary of Key Disposal Cell Design Features

The radon barrier and drainage layer are the most important design features affecting ground water resources protection. The cover design is based on the UMTRA Project "checklist" cover (DOE 1989) to ensure that the cover will perform as required and meet the 200- to 1,000-year design life, given site-specific conditions. A clean fill dike is incorporated as part of the design to prevent lateral water migration. Temporary standpipes to monitor transient drainage are discussed in Section 7.0 of this document.

The radon barrier will have a hydraulic conductivity of nominally 1×10^{-7} cm/s (NRC 1993; p 23), which is conservative in that it does not rely on limiting infiltration. So-called "bathtubbing" will be prevented by constructing the cover with an average hydraulic conductivity that is much lower than that of the underlying weathered Mancos Shale. The cover design should be effective for more than 1,000 years.

8.3 Disposal Standards and Compliance Strategy

DOE has demonstrated that the hydrogeologic characteristics of the Crescent Junction Site, combined with the disposal cell design will ensure that any leachate draining from the cell would take thousands to tens of thousands of years to reach the uppermost Dakota aquifer. This indicates that disposal of tailings in the Crescent Junction disposal cell would meet the 40 CFR 192 ground water protection requirements of being "effective for up to 1,000 years to the extent reasonably achievable, and, in any case, for at least 200 years."

Because leachate from the disposal cell is not projected to reach the uppermost aquifer, constituent concentrations in the uppermost aquifer would not exceed background levels during the period of cell performance. All seepage would be contained within the Mancos Shale confining unit. Based on site hydrogeology and cell design, leachate from the cell is expected to migrate vertically into the Mancos Shale; no surface discharge is anticipated. Hydrogeologic isolation of the cell from the uppermost aquifer and from the surface would ensure protection of human health and the environment for the design life of the cell.

Because of the effectiveness of hydrogeologic isolation, no constituents of concern need to be identified or ground water concentration limits established. No monitoring needs to be conducted to ensure protection of the ground water, and no point of compliance is required. Likewise, no corrective action plan for ground water is necessary.

8.4 Disposal Cell Components and Longevity

Provisions in 10 CFR 192.20 require that control of RRM and listed constituents be designed to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. In addition, it is required that there be a reasonable assurance the radon-222 in air will be controlled to specific standards and that listed constituents not exceed specific ground water concentration limits.

The design of the disposal cell at Crescent Junction has been configured to meet the standards in the regulations considering the appropriate technical guidance. The disposal cell components are constructed from natural materials that have been sufficiently characterized to ensure a thorough understanding of their long-term performance. These materials are to be placed in conditions that take advantage of natural processes to reduce the effects of weathering and erosive forces such that the requisite reasonable assurance of long-term performance is achieved. Specific DOE and

NRC technical guidance and methods have been used in developing the disposal cell design (e.g., DOE 1989, NRC 1989a, and NRC 1993).

End of current text

9.0 Processing Site Cleanup

9.1 Radiological Cleanup

Extensive field sampling and radiological surveys have been conducted to determine the extent and degree of contamination at the Moab Processing Site. Attachment 1, Appendix I contains data pertaining to materials contained within the tailings pile.

9.1.1 Radiological Site Characterization

Attachment 5, Appendix M, contains details for limits of RRM exceeding EPA standards within DOE's property boundaries on the former processing site. The total volume of contaminated materials being used for estimating the size of the disposal cell is 12.0 million yd^3. Measurements of background radioactivity near the Moab Site and measurements of existing radiological conditions are summarized in Table 9–1 and in Attachment 1, Appendix K.

RRM volume to be disposed of comprises a number of separate quantities: the tailings pile, the remediated off-pile soils, the remediated vicinity property materials, and the subpile soils (contamination below the pile from leaching and infiltration). The tailings pile volume was calculated using the aerial survey data from 2005 and the existing ground contours that were confirmed using borehole and CPT test data. These data were then used to cut cross sections through the pile and to calculate the volume of the tailings pile. The cross sections and the geotechnical data were then used to estimate the quantities of the three principal soils types: sands, sand-slime mixes (transitional), and slimes. A volumetric weight and moisture content was then calculated for each area of the pile; these calculations provided an estimate of the dry weight and water weight of each type of material. The in-place volume for the 130-acre tailings pile was calculated to be 9.9 million yd^3 using average maximum dry densities and moisture contents for each material type. Because of the varying moisture content between the sands, transitional material, and slimes, the weight of the material will vary as it is excavated, transported, and dried to near optimum moisture for compaction.

The subpile volumes were determined by advancing boreholes through the bottom of the tailings into underlying alluvial soils. Radium-226 activities were measured every foot to determine the maximum depth of contaminated soils that require removal. This thickness was multiplied by the footprint area of the pile to determine the volume of subpile contamination. Because of the expense to drill through the pile and the goal to not contaminate substrate, only a few borings were drilled. As a result of limited data, two extra feet of material was added to the volume estimate based on lessons learned at remediating other UMTRA Project sites. The volumes of the tailings pile and contaminated subpile soils are estimated in Attachment 1, Appendix I.

Approximately 700,000 yd^3 of off-pile RRM has been estimated over the 439-acre area within the DOE property boundary. This volume includes the areas within the highway rights-of-way, but excludes the area within the footprint of the tailings pile. Depths of contamination for the area range from 6 inches to 20 feet below grade. Concentrations of radiological contaminants range up to 1,283 pCi/g for radium-226, up to 1,154 pCi/g for total uranium, and up to 779 pCi/g for thorium-230. The details of the extent of contamination off-the pile is presented in Attachment 5, Volume II, Appendix M.

Although properties adjacent to the processing site are being assessed for extent of contamination, there is little evidence of tailings leaving the processing site and contaminating vicinity properties in the city of Moab. Consequently, an estimate of 120,000 yd^3 is being used for potential cleanup of vicinity properties adjacent to the processing site and those possibly located in the city. This amount should not vary enough to impact the final cell design.

9.1.2 Standards for Cleanup

DOE is committed to removing contaminated materials and placing them in an engineered disposal cell such that all EPA standards in 40 CFR 192 are met. The standards require that average surface (top 15 cm) radium-226 concentrations must be equal or less than five pCi/g plus background average of 0.8 pCi/g and average subsurface (below 15 cm) radium-226 concentrations must be equal or less than 15 pCi/g plus background in each 100 square meter (m^2) area. All disturbed areas will be restored for adequate control of surface drainage. All excavations are either backfilled to original grade or with a minimum of six inches of fill. Some excavations are not backfilled and are subsequently remediated to five pCi/g to meet the surface standard. Where removal of contaminated materials is not practical or feasible, application of supplemental standards may be considered according to 40 CFR 192.21.

9.1.3 Verification of Cleanup

Excavation control monitoring will be conducted during remedial action to ensure that the 5 pCi/g and 15 pCi/g above background radium-226 standards are met for surface and subsurface soils, respectively. Engineered design drawings will be developed to depict the depth of contamination and requirements for remediation. Gamma readings and soil samples will be taken to guide the depth and extent of excavation, preventing both under excavation and over excavation.

After completion of excavation, a verification measurement of the residual radium-226 concentration in each 100 m^2 area will be performed. The intent of the verification survey is to provide reasonable assurance that the remedial action has complied with the standards.

Final verification surveys will be performed to document average radium-226 concentrations on all 100 m^2 areas remediated. Nine-plug composite verification soil samples will be collected from each 100 m^2 area remediated and analyzed by on-site gamma spectroscopy to verify compliance with EPA standards. The gamma spectroscopy system shall have an accuracy of plus or minus 30 percent of the standard at the 95 percent confidence level for a sample with concentration equal to the standard. Ten percent of all verification samples are sent to an independent laboratory for verification of radium-226 and thorium-230 concentrations. When soil containing a significant fraction of small rocks is encountered, the radium-226 concentration determined by gamma spectroscopy will be corrected using approved procedures, such as Procedure 3, Section 4.7 in the Field Services Procedures Manual (STO 203).

A GPS/gamma scanning system may be used for verification in lieu of soil sampling every 100-m^2 grid. Automated gamma measurements would be taken over 100 percent of all accessible remediated areas and the exposure rate data stored in a computer. Soil samples will be taken during the excavation control process to develop a correlation between the exposure rate readings and radium-226 concentrations. A minimum of five percent of the soil grids will be composite sampled during verification to confirm the gamma to radium correlation.

Supplemental standards may be applied in areas where excessive environmental harm or worker risk outweighs the benefits of attaining the established soil cleanup standards. Based on known conditions, potential uses of supplemental standards include areas under asphalt of the state and federal highways, around high-pressure gas lines and high voltage electric lines, on steep (inaccessible) hillsides, around the Union Pacific rail track, below the water surface of the Colorado River, and around significant archaeological features.

If thorium-230 is detected in significant concentrations after radium-226 has been removed to the EPA standards, a supplemental standard under criterion (f) of 40 CFR 192.21 will be imposed. For thorium-230 contamination, the supplemental standard will be to reduce the thorium-230 concentration to a level such that the radium-226 concentration in 1,000 years, including residual and ingrown radium-226, will not exceed 15 pCi/g in subsurface soil.

Independent radiological surveillances and health and safety audits will be conducted by DOE and its Technical Assistance Contractor during remedial action to ensure that all activities are conducted to meet federal, state, local, and UMTRA Project standards and guidelines. Quality control and quality assurance requirements and procedures are in place to ensure that adequate cleanup and subsequent verification are properly implemented and documented.

Table 9–1. Background Radioactivity and Radiological Conditions at the Moab Site

Description	Range	Average
Gamma Exposure Rate		
Background	11–15 μR/h	12 μR/h
Above tailings pile	60–830 μR/h	–
Off-pile	14–4,500 μR/h	–
Radon-222 in Air		
Background	0.4–1.3 pCi/L	0.7 pCi/L
Flux from tailings pile	2–318 pCi/m^2/s	104 pCi/m^2/s
Soil Concentrations		
Background radium-226	0.4–1.7 pCi/g	0.8 pCi/g
Total uranium	0.5–2.6 pCi/g	1.2 pCi/g
Tailings pile radium-226	13–2,195 pCi/g	707 pCi/g
Off-pile radium-226	1–1,283 pCi/g	–

μR/h = microroentgens per hour

9.2 Ground Water Cleanup

Ground water contamination and conditions at the Moab Processing Site were described and evaluated in the SOWP (DOE 2003). Ground water remediation was also evaluated in the EIS for the Moab Site (DOE 2005), in which the preferred alternative was identified as active ground water remediation. An interim action for ground water cleanup was initiated in 2003 and has been operating and expanded since that time. A final decision regarding long-term ground water cleanup approaches and remediation goals will be deferred until a later date and documented in a subsequent Ground Water Compliance Action Plan (GCAP) according to the requirements of 40 CFR 192.

Human health and the environment will not be affected by deferring the final ground water remedial action in the uppermost aquifer (alluvium) at the Moab Processing Site until the cleanup of RRM has been completed. The interim action ground water program is limiting discharge of contaminants to the environment and there is no public exposure to the ground water as the existing wells are being used for either monitoring or ground water cleanup.

The main concern regarding contaminated ground water at the Moab Processing Site is how its discharge to the Colorado River might affect surface water quality and, in turn, affect potential habitat for endangered fish that are known to be present in that segment of the river. The current ground water and surface water monitoring programs at the Moab Processing Site are focused on these concerns and will be continued as deemed necessary during and beyond the remediation process. Several different tasks are currently being carried out by DOE as required by the U.S. Fish and Wildlife Service's final Biological Opinion, issued as part of the Final EIS for the site (DOE 2005).

9.2.1 Ground Water Cleanup Standards

Because of the high natural salinity of ground water at the Moab Processing Site, the alluvial aquifer qualifies for supplemental standards. Ground water cleanup is only required to be protective of human health and the environment where it could affect other usable water bodies (e.g., the Colorado River). Therefore, the focus of ground water cleanup efforts has been on improving surface water quality rather than meeting numerical ground water standards.

9.2.2 Cleanup Demonstration

Specific cleanup goals and means of demonstrating that they have been met will be discussed in the future in the GCAP for the Moab Processing Site. Results of ongoing monitoring at the site will be used to help formulate this approach.

9.2.3 Ground Water and Surface Water Monitoring Programs

Several different types of monitoring are ongoing at the processing site. These include routine surface water and ground water sampling, interim action surface water and ground water sampling, and biomonitoring of the Colorado River.

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DOE–EM/GJ1547

Office of Environmental Management – Grand Junction

UMTRA Project

Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

Addendum A through E

February 2008

U.S. Department of Energy

Office of Environmental Management

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ADDENDUM A

Final Remedial Action Plan
DOE-EM/GJ1547
February 2008

DOE Responses to NRC Comments

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ADDENDUM A – NRC COMMENTS AND DOE RESPONSES

April 2006 Meeting

Geology

1(a). "Linear feature - explain further why the stratigraphy of the Prairie Canyon Member defines the lineament..." It is asserted that the lineament is stratigraphically controlled, i.e., there is little direct technical support provided in the RAP that an informed reviewer could rely on to concur. The nature of the contact of the two members of Mancos Shale that are adjacent to or directly underlie the footprint take on importance for understanding present and future site conditions and the behavior of surface and ground water that flows across and through the contact zone. If the contact is stratigraphic, explain why is it not linear everywhere it is exposed. If the lineament cannot be explained definitively as stratigraphic, then it may be structural, such as a fault contact. Such a possibility would entail investigating whether or not it is a capable fault.

1(b). "...and that the linear feature is not offset by faults." The applicant's idea of explaining why the linear feature is not offset by faults (and the significance of such an observation) is potentially useful for showing structural integrity of the lineament only where it is exposed to scrutiny.

Response for 1(a) and 1(b):
The stratigraphic horizon referenced in this comment is represented by discontinuous concretionary masses of dolomitic siltstone that mark the top of the Prairie Canyon Member. These resistant concretionary masses are near the north edge of the disposal cell footprint in the south parts of Sections 22 and 23, as shown in the March 12, 2007, geologic map. Exposures of this stratigraphic horizon are not linear everywhere because the exposures are characteristically poor and the concretionary masses are discontinuous both along strike and along dip. Additionally, subtle spatial variations in strike and dip directions within the Mancos Shale, coupled with the topographic elevation of the individual exposures, cause the exposed masses to appear nonlinear in outcrop. Stratigraphic characteristics of the Prairie Canyon Member of the Mancos Shale at the Crescent Junction Site are similar to the descriptions provided in two important references (listed here).

Cole, R.D., R.G. Young, and G.C. Willis, 1997. *The Prairie Canyon Member, a New Unit of the Upper Cretaceous Mancos Shale, West-Central Colorado and East-Central Utah,* Utah Geological Survey Miscellaneous Publication 97-4.

Hampson, G.J., J.A. Howell, and S.S. Flint, 1999. "A Sedimentological and Sequence Stratigraphic Re-Interpretation of the Upper Cretaceous Prairie Canyon Member ("Mancos B") and Associated Strata, Book Cliffs Area, Utah, U.S.A.," *Journal of Sedimentary Research*, 69(2), pp. 414–433.

The revised calculation set for Surficial and Bedrock Geology of the Crescent Junction Disposal Site (Attachment 2, Appendix B) includes additional mapping results, stratigraphic descriptions, and literature citations that describe this important horizon in the Prairie Canyon Member.

2. "Provide photo(s) from the top of the Book Cliffs showing the lineament." [does not affect RAP]. This request was made to enable the NRC staff to inspect the lineament more clearly in a larger form than what is in the draft RAP.

Response:
Four photographs taken on July 19, 2005, from the top of the Book Cliffs just north of the site, showing the subject lineament, were sent to the NRC on May 3, 2006, for their inspection.

3. "Linear feature - evaluate any geophysical reflection data on fracture orientations in boreholes (005 and 023) and corehole (0201) north of the lineament." The objective of such investigations appears to be to obtain data on the characteristics of the contact zone and to seek evidence for the origin of the lineament. Such data may be potentially useful for assessing the geomechanical properties of the rocks, flow and transport properties and conceptual models of the rocks at and near the site.

Response:
Geophysical seismic surveys conducted at the site consisted of the refraction rather than the reflection method. The refraction survey was conducted to obtain shear wave velocities in the weathered Mancos Shale to determine its rippability characteristics. The refraction survey area was south of the lineament, and this survey method would not provide useful data for a lineament investigation.

4. "Low sun-angle photos - send a copy to NRC for inspection." [does not affect RAP]. The request was made because the photos were identified, but not provided in the draft RAP.

Response:
A set of low sun-angle photographs taken on July 27, 2005, was sent to the NRC on May 3, 2006, for their inspection.

5(a). "Document/evaluate rates of changes of surface geologic processes such as scarp retreat of the Book Cliffs…"

5(b). "…rock falls and roll distances (petroglyph dates),..." These geomorphic processes result in (i) erosion of the cliffs that dominate the site by gravity, running water and wind, (ii) the transport of rock particles of all sizes up to large boulders, and (iii) the deposition of the rock particles. The smaller particles, sizes up to small boulders, are shown on photos and reported to have been transported to (and impinge upon) the proposed footprint and beyond (lower elevations), largely by sheet wash. There is a need to quantify or otherwise bound the sediment loading of the surface drainage system for the next 200 to 1,000 years as input to the design of the empoundment to achieve the necessary performance.

Response for 5(a) and 5(b):
Northward scarp retreat of the Book Cliffs was estimated from average scarp retreat rates in the literature (listed here) for the Book Cliffs and for rock types in arid environments at 5 feet (ft) per thousand years.

Schumm, S.A., and R.J. Chorley, 1983. *Geomorphic Controls on the Management of Nuclear Waste*, prepared for the U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-3276.

Woodward-Clyde Consultants, 1983. *Overview of the Regional Geology of the Paradox Basin Study Region,* unpublished technical report ONWI-92, prepared for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, March.

Rock art (petroglyphs) on several boulders at the base of the Book Cliffs is from the Fremont era of 200 BC to 1350 AD. This gives a minimum age of the rock falls as 650 years, but they could have fallen as long as 2,200 years or more ago. Calculation of the rock fall runout distance for rocks falling from the top of the Book Cliffs was made along two profiles, using an empirical angle that defines the limit of runout. Distances from the empirical rock-fall runout limits from the two profiles to the edge of the disposal cell footprint were 900 and 950 ft. This indicates the disposal cell and any access roads or infrastructure are far enough from the base of the Book Cliffs to not pose a hazard from rock falls.

The scarp retreat rate information was included in the revised calculation set for Site and Regional Geomorphology – Results of Literature Research (RAP Attachment 2, Appendix C). Information on rock-fall runout distances was included in the revised calculation set for Site and Regional Geomorphology   Results of Site Investigations (Attachment 2, Appendix D).

5(c). "...and rate of incision (headcutting) migration of West Kendall and Crescent Washes." In fact, the potential hazard to the proposed empoundment from any stream, wash or gully that may erode headward and intersect or otherwise affect the empoundment in the next 200 to 1,000 years needs to be fully investigated and evaluated as potential inputs to design for mitigation.

Response for 5(c):
Forecasts of headward erosion are in the revised calculation set for Photogeologic Interpretation and in the revised calculation set for Site and Regional Geomorphology Results of Site Investigations (RAP Attachment 2, Appendices G and D, respectively). The progress of headward incision of three tributaries of the West Branch of Kendall Wash was compared in the registered historical aerial photographs from 1944, 1974, and 2005. Results showed the progress of headcuts was approximately 1.3 to 2.3 ft per year over the 60-year period. At these rates, headward erosion would reach the site access road in about 250 years and just outside the southwest corner of the disposal cell in about another 250 years. Approximately 1,600 years of headcutting would be required to reach

northwestward to Crescent Wash, where a capture of that drainage by the West Branch would be possible.

To protect the disposal cell from the headcutting, the outlet of the main diversion channel coming from the north side of the disposal cell has been extended away from the cell and with sufficient riprap at the outlet. In addition, a rock apron was also designed around the toe of the east, west, and south sides of the cell to protect against erosion and dissipate energy from cell runoff.

6(a). "Evaluate the effect (if any) of fractures on weathered Mancos Shale and on hydrology."

Because fractures exist at the site and beyond (from observations of pits, core and outcrops) in weathered (and unweathered) Mancos Shale, characteristics of fractures in both the Prairie Canyon and Blue Gate Members should be investigated only to the level of detail commensurate with their significance to design and to performance evaluations.

6(b). Suggest DOE prepare explicit characteristics of "weathered" and "unweathered" Members of the Mancos Shale, given that these are end members of a gradational series. The goal is to minimize ambiguous data from samples that are partially weathered or partially unweathered. Implicit in the description of the characteristics of the weathered Mancos Shale, such as fractures, is the need to describe the characteristics that distinguish the weathered Mancos Shale from the bedrock Mancos Shale (for both the Prairie Canyon and Blue Gate Members). DOE stated at the meeting that the weathered zone of the Mancos grades gradually into the unweathered (bedrock) Mancos, making it necessary to describe criteria to distinguish each type of shale.

Response for 6(a) and 6(b):
Characteristics of weathered and unweathered Mancos Shale bedrock for both the Prairie Canyon and Blue Gate Members were compiled from corehole lithologic logs and RQD data and are in Figure 8 in the revised calculation set for Surficial and Bedrock Geology of the Crescent Junction Disposal Site (RAP Attachment 2, Appendix B).

7. "Evaluate more fully the reason(s) for the abandonment of the course of the ancestral East Branch of Kendall Wash and assess if future drainage abandonments could occur and their affect on the site." The significance of a stream abandonment on a bajada or pediment for understanding future stability or predictability of drainage networks depends on the cause(s), rates of reestablishment of the drainage change, and future site conditions. The observation of large boulders in a wash in or near the abandoned system unusually far from the Book Cliffs suggests the possibility that a highly energetic, but localized, wash may occur again in a situation similar to that of the proposed footprint.

Response:
Additional characterization of the withdrawal area east of the proposed disposal cell footprint (including the East Branch) was conducted in October 2006. Several additional areas of large boulders were found associated with the East Branch and its ancestral drainages. These areas are at least 1 mile (mi) east of the disposal cell footprint and appear

to be expressions of high-energy flows from the East Branch drainage system that heads in two canyons (known as Little Blaze Canyon and an unnamed canyon just to the west of it) that are reentrants into the Book Cliffs. Based on the difference in the depths of incision of the ancestral East Branch and the present East Branch at the point of capture, capture of the ancestral East Branch occurred approximately 6,000 to 9,000 years ago.

This additional information and the implications for the disposal cell area were included in the revised calculation set for Photogeologic Interpretation (RAP Attachment 2, Appendix G).

8. "Erosion surfaces appear to be displaced from aerial photos - determine if they are displaced and their significance if they show Quaternary movement." Because displaced erosion surfaces may have been caused by neotectonic activity, they are potential clues to seismic sources. They may be also caused by a seismic structural deformation. Such potential surfaces were reported in RAP Attachment 2, Appendix G, Plate 1 and captions 'g' and 'h' for Low Sun Angle photograph.

Response:
Area "g" was investigated in May 2006 and determined not to be related to faulting. It had appeared from aerial photographs that Crescent Bench, a mantled pediment surface, was displaced down to the north. Upon inspection, the lower surface was not the same mantled surface as Crescent Bench; it was an unmantled surface on Mancos Shale, and the difference in height of the two surfaces could be explained simply by erosion rather than faulting.

Possible displacement of the Quaternary surface along a linear feature at area "h" was investigated in November 2006. No displacement was seen and the linear feature was determined to be an old dozer cut about 2 mi long made for a seismic survey line probably in the 1960s. Results from investigations of both areas "g" and "h" were included in the revised calculation set for Photogeologic Interpretation (RAP Attachment 2, Appendix G).

9. "Expand the discussion on potential natural resources (oil/gas, salt/potash, uranium/vanadium, and gold) based on current economics." An update is prudent, given that gold is near its all time high and oil is at its all time high, for example.

Response:
Oil and gas are the geologic resources that have the highest potential for occurrence and development at the site area. The entire withdrawal area is currently leased for oil and gas, and several oil and gas test holes have been drilled recently just to the south and west of the withdrawal area. Exploration and production of oil and gas (if it occurs) is permitted in the withdrawal area and production could take place even under the 250-acre disposal cell by directional drilling.

The probability of occurrence of potash and other salt mineral resources is low in the site area because of post-depositional movement of the saline facies of the Paradox Formation toward the axis of the Salt Valley Anticline about 2 mi to the southwest of the site. As a result, these deposits at the site are thin to absent. Uranium and vanadium and copper and silver deposits are in the Morrison Formation in widely scattered locations more than 5 mi south of the site area; the low probability of the occurrence of these metals beneath the site and the greater than 3,000-foot depth of the Morrison Formation make their exploration and development economically unfeasible. Gold content is slightly higher in Mancos Shale in the site area than what normally occurs in shale; however, to warrant economic extraction, the gold content would have to be 10 to 100 times higher.

Additional information on these potential natural resources in the site area is in the revised calculation set for Site and Regional Geology Results of Literature Research (RAP Attachment 2, Appendix A). The discussion is based primarily on two BLM reports, which give the occurrence and development potential of these resources.

10. "If oil/gas resources are present below the site, and these were exploited, could subsidence (and how much?) occur?"

Response:
Possible oil and gas production from beneath the disposal site at depths of between 4,000 and 11,000 ft would not result in subsidence. Void (pore) space in the rock (typically a sandstone) that would contain the oil and/or gas typically amounts to as much as 20 to 25 percent of the rock volume. Recovery of the oil and/or gas (usually less than 50 percent of the resource) would therefore result in creating a void space consisting of only about 10% of the rock volume. Adequate grain support in the well-lithified sandstone of Paleozoic or Mesozoic age and the great depths of the possible production horizons would make surface subsidence highly improbable. No subsidence has been reported as a result of oil and gas production from numerous fields at similar depths in east-central Utah (personal communication in 2007 with David Tabet, Geologic Manager of Energy and Minerals Program for the Utah Geological Survey). This information was added to the Resource Development section in the revised calculation set for Site and Regional Geology Results of Literature Research (RAP Attachment 2, Appendix A).

11. "Further document the past occurrence of shallow gas in the Mancos Shale and its potential to occur at the site." Given that DOE reported evidence of natural gas in at least one of its boreholes on or near the site, that gas blowout preventers have been used by local drillers because of a known (little evidence presented) or presumed hazard, it is prudent to investigate the history, likelihood, expected magnitude of such a hazard at the site or at analogous sites in the area.

Response:
More details of the occurrence of gas in one borehole from the 1920s were added to the revised calculation set for Site and Regional Geology Results of Literature Research (RAP Attachment 2, Appendix A). No other shallow test wells from the area have reported gas, but the occurrence of gas in thick marine shale is not unusual.

12. From Disposal Cell Section: "The sheet flow process described in the geology section is expected to continue after cell construction and must be considered in the design." From a geological review perspective, the description of the sheet flow hazard (in the Geology Section) would need a technical basis to support an estimation of locations, rates and magnitudes of water and mass movements over the next 200 to 1,000 years.

Response:
Because the disposal cell is designed such that maximum flows coming down the main sheet wash path (in the east part of the cell) would be diverted westward and eastward around the perimeter of the disposal cell, sheet wash flow is not considered a hazard and determination of the rate of accumulation of sheet wash deposits is not necessary.

Seismology

13. "Indicate which faults are capable/not capable and basis for assumption." Identify the known and suspected faults in the area such that if any were of such size and distance from the site that, if seismogenic, would affect the site and need to be evaluated for its seismic loading potential.

Response:
Faults are identified as capable/not capable in the revised calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, Table 3). Known and suspected faults are identified and discussed in the revised calculation set for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E, pages 5–12).

14. Provide rationale for using 6.2 for the floating earthquake when 5.9 is listed as the maximum earthquake on page 6.

Response:
Rationale to explain the difference between the estimation of the maximum predicted earthquake and the maximum historically recorded event is explained in the revised calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, page 5).

15. Indicate why some faults included in the calculations for the Cheney Site were not included for the Crescent Junction Site.

Response:
An explanation is given in the revised calculation set for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E, page 11) that although the Cheney Site is used as a comparison for a site within the same tectonic province, the sites are not in the same location, so faults located closer to one site will have the potential of having larger impacts on the close site as compared to the farther site. Specific faults will be addressed on an individual basis that is relevant to both sites.

16. Provide velocity data from geophysics for the rippability study for the weathered and unweathered Mancos Shale below the site.

Response:
The geophysical investigation at the Crescent Junction Site was done specifically to access rippability of the Mancos Shale during construction of the disposal cell. As such, the investigation consisted of determining the seismic velocities of the weathered and unweathered shale deposits using compression wave data. Shear wave velocities and shear modulus are typically the parameters used to evaluate the stiffness of the foundational materials to evaluate if amplification of ground motions would be expected. However, on a qualitative basis, the seismic velocity data will be presented to support the claim that site amplifications will be negligible. Velocity data are provided in the revised calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, page 17).

17. Provide more justification to support the salt dissolution origin for the Thompson Anticline and Tenmile Graben structures.

Response:
A preliminary field investigation of several unnamed faults, associated with the Thompson Anticline (Willis 1986; Doelling 2001), showed no evidence of Quaternary movement (no Quaternary deposits were displaced by the faults). It was concluded that no recent movement has occurred along faults associated with the Thompson Anticline, and that they reflect slow, incipient subsidence related to dissolution of deep salt deposits along the northeast edge of the Paradox Basin.

The Tenmile Graben, which is approximately 35 km long, is a narrow zone of faulting displacing Cretaceous and Jurassic bedrock along Salt Wash southeast of the town of Green River. The graben is on the northwestern edge of an area typified by northwest-trending, elongated oval valleys that are collapsed or depressed anticlines. The graben is probably related to salt dissolution. The youngest rocks offset by this fault are the upper members of the Cretaceous Mancos Shale (Doelling 2001). No Tertiary rocks are preserved along the Tenmile Graben. Quaternary alluvium and eolian sediments do not appear offset by any of the faults (Doelling 2001). Because no evidence exists for Quaternary deformation of the Tenmile Graben, it is not considered a capable fault for seismic-hazard assessment purposes.

Further discussion is presented in RAP Attachment 2, Appendix E, pages 6–7 and 10–12.

18. Determine if Granite Creek and Ryan Creek Faults on the Uncompahgre Uplift are connected and what acceleration would result.

Response:
The possibility of Granite Creek and Ryan Creek Fault systems being connected was investigated. The two fault systems appear to be separate based on mapping both by Doelling (2001) and in a cross section by Ely et al. (1986). Because the Granite Creek and Ryan Creek Faults are roughly parallel and overlapping, the total fault trace would not increase if they were considered collectively. Several faults of similar strike parallel the Granite Creek Fault to the northeast. Both Granite Creek and Ryan Creek Faults may

merge at depth with the major uplift-bounding (Uncompahgre) reverse fault. For purposes of the Moab Remedial Action Plan, the Granite Creek Fault zone is considered a capable fault.

Discussion on the connectivity of these faults is given in the revised calculation set for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E).

19. In Appendix B Table, change the Wells and Coppersmith rupture-length reference to Campbell.

Response:
The table in calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F), has been adjusted to make column headings more clear.

20. Provide latitude and longitude for fault systems in tables.

Response:
Latitudes and longitudes have been shown on all figures in the revised calculation sets for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E) and Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F).

21. Provide copy of Cheney RAP.

Response:
The Cheney RAP was sent to the NRC on May 3, 2006.

22. Provide justification for using 0.42 g for Cheney design while 0.21 g for Crescent Junction.

Response:
According to the revised calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, page 18), the seismotectonic stability studies done for the Grand Junction mill tailings/Cheney Disposal Site identified a fault (Fault 8) with a length of 11.0 km at a distance of 9.0 km from the site. Although no evidence of Quaternary displacement was proven, it was considered to be capable on the basis of its apparent association with a possibly active regional structure, the Uncompahgre Uplift. This fault was adopted as the design fault for the Cheney Disposal Site, resulting in a recommended design acceleration of 0.42g. The capabilities of this fault and other faults related to the Uncompahgre Uplift have negligible impact on the Crescent Junction Site due to the distance of these faults to the Crescent Junction Site.

23. Address amplification when estimating the seismic design for the site.

Response:
The TAD (DOE 1989) states in Section 5.4.4 that for shallow soil sites with less than 30 ft of overburden above bedrock, the site surface acceleration is considered to be the same as the acceleration derived from the seismic study. In Campbell and Bozorgnia (2003) attenuation relations, the PHA equations account for local site conditions of the upper 30 meters of rock or soil. As defined in their paper, the site is categorized as a firm rock site, based on underlying geologic unit consisting of pre-Tertiary sedimentary rock (Late Cretaceous Mancos Shale). This category assignment is supported by the SPT data, which place the less-weathered Mancos Shale as a BC soil class as defined by the National Earthquake Hazard Reduction Program.

A discussion of amplification at the site is presented in the revised calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, page 17).

24. Provide any available reflection or geophysical data which may shed light on the stratigraphy and seismic velocity at the site.

Response:
Seismic velocity data from the rippability study summarized the three main geologic layers. The upper layer (alluvium and eolian deposits) ranged in depths from 4.5 to 18 ft, with seismic velocities ranging from approximately 1,160 to 1,330 feet per second (fps), typical for unsaturated alluvial overburden soils. The base of the second layer (weathered Mancos Shale) was interpreted to vary between approximately 24 and 60 ft, with seismic velocities ranging from about 4,060 to 5,220 fps. Velocities for the unweathered Mancos Shale ranged from about 9,000 to 10,000 fps. These data are provided in the revised calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, page 17).

25. Make sure the earthquake distributions in Fig. 4 App. (E) are consistent with those in Fig. 1 App. (F).

Response:
Modifications were made for consistency in the revised calculation sets for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E, Figure 4) and Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F, Figure 1).

26. Identify the different symbols in App. (E/B) and App. (F/A).

Response:
In RAP Attachment 2, the Appendixes have been modified in the revised calculation sets for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E) and Site and Regional Seismicity – Results of Maximum Credible

Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F).

27. Address if liquefaction may occur at the site.

Response:
Tailings liquefaction is not likely because tailings would be placed in the cell at near-optimum moisture conditions (i.e., unsaturated), at compaction densities achieved with placement in lifts and rolling with construction equipment, and the fines content of the tailings. In the event that zones of tailings do become saturated, the calculated stress ratio required to cause liquefaction of the tailings is higher than the seismic stress ratio for all of the cases considered, indicating that liquefaction would not occur. Liquefaction is discussed in the revised calculation set for Settlement, Cracking, and Liquefaction Analysis (RAP Attachment 1, Appendix D).

June 2006 Meeting

Ground Water Hydrology

1. What is the deepest weathered Mancos Shale encountered at other sites? Is it similar to the approximately 20-foot (ft) thickness found at the Crescent Junction Site?

Response:
The weathered zone in the Mancos Shale at the Shiprock, New Mexico, Legacy Management Site is approximately the same thickness as the weathered Mancos Shale at the Crescent Junction Disposal Site. Packer tests conducted at the Shiprock Site suggest that the weathered zone (the zone with relatively higher permeabilities) extends to a depth of approximately 35 ft. Below that depth, the permeabilities are approximately 3 to 4 orders of magnitude lower than in the upper weathered zone.

2. What is the basis for concluding that water encountered in the 300-ft-deep characterization holes is connate?

Response:
The ground water in the Mancos Shale is suspected to be connate based on several factors, including its salinity, variable ground water levels, and isolation from sources of recharge. In August 2006, the ground water was sampled in wells 0203 and 0208 and analyzed for radiocarbon (^{14}C). Results of the analyses show that the age of the ground water exceeds 40,000 years, which is the approximate detection limit for radiocarbon age dating. A calculation set describing the results of ^{14}C dating of ground water from two wells (0203 and 0208) at the disposal site is included in a new calculation set for Radiocarbon Age Determinations for Ground Water Samples Obtained From Wells 0203 and 0208 (RAP Attachment 3, Appendix F).

Water Resources Protection Strategy

3. Provide geochemistry data on water from the 300-foot-deep holes.

Response:
A hard copy of the requested data was provided to NRC at the meeting. A summary of geochemistry data for the Crescent Junction Site is included in RAP Attachment 5, Appendix H, Background Ground Water Quality.

Disposal Cell Design and Engineering Specifications

4. Recommendation was made on rock size and filter requirements that only the Abt-Johnson method and not the Stephenson method be used with the objective of reducing filter layer thicknesses and rock thickness and size on the side slopes. Ted Johnson indicated that perhaps only the south side slope and the drainage channel(s) may require a filter layer (east, west, and north side slopes may not require a filter layer), but a thinner filter layer could be used. Also, the thickness of the rock does not have to be twice the D_{50}, and that 1.5 times the D_{50} would suffice.

Response:
The calculation set for Erosional Protection of Disposal Cell Cover (RAP Attachment 1, Appendix H) was revised using the Abt-Johnson method, which reduces the size of the rock on the side slopes. The filter layer will be eliminated on the east, west, and north side slopes, but is necessary on the south side slope to accommodate runoff from the surface of the disposal cell. A filter layer will also be used under the riprap along the toe of the north side slope. The rock layer thickness will be kept at twice the D50 or near the D100 size requirements.

5. The proposed toe protection on the south side slope for a scour depth of 1 foot is too low, as cited in Figure 4 in the calculation set for Erosion Protection of Disposal Cell Cover. The total thickness of the rock was acceptable, but the thickness of rock for protection of the south slope apron should be re-evaluated according to NUREG-1623, page D-19.

Response:
The apron protection on the south slope was recalculated to be 2.5 ft deep, and this was incorporated in the calculation set for Erosional Protection of Disposal Cell Cover (RAP Attachment 1, Appendix H).

6. The issue was discussed on how to handle sedimentation in the north drainage channel from small precipitation events while maintaining a full channel to accommodate the Probable Maximum Precipitation. Suggestion was made that DOE consider eliminating the north drainage channel and just use toe protection buried below grade as is proposed for the south side slope.

Response:
Diversion of upland runoff around the north side of the disposal cell involves conveying runoff to the west of the cell without eroding materials at the toe of the north slope of the cell. Diversion also involves accommodation of sediment from upland runoff that may settle out due to the decrease in gradient from 2 percent (in upland areas) to 0.5 percent (along the toe of the north slope). These factors are included in the current design along the north slope of the disposal cell. Erosion protection along the north slope of the disposal cell will consist of (1) a rock mulch on the slope above the anticipated level of flow along the toe of slope, (2) riprap on the slope within the anticipated level of flow along the toe of slope, (3) riprap on an apron extending from the toe of slope and (4) buried riprap in a trench beneath the apron, extending below the estimated depth of scour. A channel will be constructed along the toe of the north slope to facilitate placement of erosion protection materials; the channel will drain to the west-southwest at a 0.5 percent slope, and it is anticipated that it will fill with sediment from upland runoff. The above design changes were incorporated in the revised calculation set for Diversion Channel Design, North Side Disposal Cell (RAP Attachment 1, Appendix G).

7. The NRC agrees with construction of a cut-off wall at the end of the north drainage channel. Instead of using a gabion basket for this wall, use of a rock-filled trench is proposed. This is because the basket wire will deteriorate during the 1,000 year life of the cell.

   Response:
   A rock-filled trench will be used without the gabion baskets. This design change was incorporated in the revised calculation set for Diversion Channel Design, North Side Disposal Cell (RAP Attachment 1, Appendix G).

8. The proposed radon barrier is highly conservative and DOE can re-evaluate in the interest of reducing layer thicknesses. Major factors influencing radon barrier thickness are the Ra-226 concentration of tailings and, to a lesser degree, the moisture content of the barrier.

   Response:
   The Ra-226 values have been revised in the calculation set for Average Radium-226 Concentration for the Moab Tailings Pile (RAP Attachment 1, Appendix K) to reflect the average of known concentrations. Previous Ra-226 values (one standard deviation above the mean) were 868 to 954 pCi/g. The updated mean Ra-226 value for the Moab pile is 707 pCi/g.

9. NRC contends that placement of contaminated railroad ties in the disposal cell will not pose a problem because they are creosote treated and will be exposed to very little moisture over the long term.

   Response:
   None required.

Vicinity Properties

10. DOE will continue to do gamma screening surveys on the 1971 EPA list as time/budget allows. If vicinity property remediation is done where contamination was left in place above 40 CFR 192 standards (Supplemental Standards), NRC will review/approve the completion report and application for Supplemental Standards. If no Supplemental Standards are applied, NRC will not review/approve the completion report.

    Response:
    None required.

General

11. NRC believes that later in the UMTRA Project, draft and final RAPs were merged into one document. NRC explained that ultimately the RAP needs to contain construction specifications and drawings (e.g. the documents that would be bid upon for the remediation work). DOE explained that because of contractual matters regarding conceptual versus final design, there will likely be a distinction in the draft versus final (degree of completeness).

Response:
The draft RAP will not contain detailed plans or specifications. The draft RAP does include an outline of technical specifications for construction and reclamation of the disposal cell to provide input on how the disposal cell will be constructed and how construction quality assurance testing will be conducted. DOE's current contractor does not have the contractual scope to complete these documents. To facilitate review and approval of the final RAP, DOE is still seeking NRC's review of the draft to ensure that the Crescent Junction Site and proposed design features meet applicable NRC guidance and the standards set forth in title 40 of the *Code of Federal Regulations* (40 CFR 192. U.S. Environmental Protection Agency (EPA), "Promulgated Standards for Remedial Actions at Inactive Uranium Processing Sites"). Based on the draft RAP and NRC comments, DOE's new contractor in 2007 can complete the detailed plans and specifications and submit a final RAP.

2007 Request for Additional Information

Geology and Seismology

G1. Geomorphology: Provide additional evidence that the discontinuous east-striking line of low, north-dipping, cuesta-like mounds just north of the disposal cell footprint near the top of the Prairie Canyon Member of the Mancos Shale are formed by resistant dolomitic siltstone concretions.

RASR, page 2-7, section 2.3.3. The text indicates "geomorphic features include......(4) a discontinuous east-striking line of low, north-dipping, cuesta-like mounds formed by resistant dolomitic siltstone concretions near the top of the Prairie Canyon Member of the Mancos Shale just north of the disposal cell footprint." This linear feature also shows up on most aerial photographs of the site and was visited during the site visit in December 2006. These cuesta-like mounds may have been formed by resistant dolomitic siltstone concretions, but additional evidence should be provided that this is the case and is not a structurally-controlled feature, possibly a fault. Are there analogous mounds in other locations away from the site where the top of the Prairie Canyon Member of the Mancos Shale outcrops producing similar cuesta-like features or is there other evidence to support the mounds have been formed due to resistant dolomitic siltstone concretions?

Response:
See response for 1(a) and 1(b) in the NRC Comments and DOE Responses for the April 2006 Meeting.

G2. Geomorphology: Evaluate headcutting rates for West Branch Kendall Wash and evaluate the possibility of stream capture of Crescent Wash by West Branch Kendall Wash.

RASR, page 2-7, section 2.3.3. The text indicates "geomorphic features include......(6) incised channels of the West and East Branches of Kendall Wash and the slow northward advance of headward incision of the West Branch of Kendall Wash." West Branch Kendall Wash is experiencing headcutting. This head cutting is progressing toward Crescent Wash. Text in section 2.4.1 indicates this headward advance will have to be monitored. Additionally, in the RASR Appendix A, DOE has committed to obtaining aerial photographs from 1944 to try to determine headcutting rates. Stream capture was verified on the abandoned wash shown as number 5 on the high-altitude vertical photographs, and this possibility should be explored for West Branch Kendall Wash.

Response:
See response for 5(c) in the NRC Comments and DOE Responses for the April 2006 Meeting.

G3. Geomorphology: Determine why constant roadway maintenance is required for Route 70 in the vicinity of the site and determine if similar problems could occur with the disposal cell.

RASR, page 2-7, section 2.3.4. The text describes "constant roadway maintenance required for Interstate Highway 70, which traverses Mancos Shale just south of the site." The text indicates that "analyses of the Mancos Shale and Mancos Shale-derived soils did not show the presence of swelling clay or highly plastic materials at the Crescent Junction Disposal Site." It appears DOE has assumed that road failures are due to montmorillonite clays and since montmorillonite clays are not present at the cell site the hazard does not exist. Has DOE considered that road failure is due to something other than montmorillonite swelling clay that may also be present at the Crescent Junction cell site? Interstate 70 and the cell will be located on the same geologic material and the maintenance problems encountered on 1-70 should be investigated fully to determine if they could occur on or within the cell.

Response:
Expanded discussion of the well-known problem of swelling clay because of the presence of montmorillonite in Mancos Shale is included in the revised calculation set for Site and Regional Geology – Results of Literature Research (RAP Attachment 2, Appendix A). Rigid concrete pavement and concrete slab structures pose a problem if built on swelling Mancos Shale. If no such structures are constructed at the disposal cell, then the swelling clay should not pose a hazard. The text of the RAS Report was changed to restate the results of analyses of Mancos Shale and Mancos Shale-derived soils.

G4. Geomorphology: Clarify the depth of the disposal cell and on what material the cell will be constructed.

RASR, page 4-3, section 4.1.2. Text in this section indicates "the disposal cell excavation is anticipated to be into the Quaternary materials, as well as into upper portions of the weathered and fractured Mancos Shale." On page 7-1, section 7.0, the text indicates the anticipated depth of excavation is 15 to 20 feet (ft). Figure 7-2 shows the excavation limits as approximately 10 ft below bedrock. Figure 7-3 shows the cell directly on the weathered Mancos Shale contact. It is unclear how far the cell will be placed into the Quaternary alluvial material and/or the weathered and fractured shale. Will the top several feet of weathered shale be removed or will the cell be placed directly on the first contact of the weathered Mancos Shale? The depth of the cell and what material the cell will be placed on should be clearly stated and consistent throughout the Report.

Response:
The base of the disposal cell will grade to the south at approximately a 2 percent slope, roughly following existing grades. Typical sections that cut north-south and east-west through the disposal cell, as well as the section locations, are shown on the revised figures in Section 7 of the RAS. The depth of excavation across the site varies in limited areas from as shallow as approximately 12 ft to as deep as approximately 21 ft. On an average basis, the depth of excavation is approximately 16 ft.

Also shown on the figures is the approximate contact between the Quaternary alluvial soils and weathered Mancos Shale, as estimated from borehole and corehole data. On average, the excavation will be approximately 11 ft in Quaternary alluvial soils, and approximately 5 ft in weathered Mancos Shale. There is a small area in which the Mancos Shale is estimated to be slightly below the excavation depth. In this area, a small remnant of the Quaternary alluvial soils will be left in place. This area is internal to the disposal cell. Therefore, the remnant of alluvial soils will not act as a pathway for seepage migration out of the disposal cell. In the area of the dikes, a minimum of 5 ft of excavation into the weathered Mancos Shale will be required in order to prevent a lateral pathway for flow out of the disposal cell.

A revised Figure 7–2, a new Figure 7–3, and a revised Figure 7–4 have been inserted into Section 7.0 of the RAS.

G5. Geomorphology: Discuss slump features identified near the site. Indicate why slumping will or will not have an impact on the site during the compliance period.

Attachment 2, Appendix G, High-Altitude Vertical Photographs (6), page 3. There is mention of a slump block or mass-wasting feature on the north side on the Book Cliffs in Horse Haven and at several other locations. The text indicates the slides were likely initiated in wetter times during the Pleistocene. What is the basis for this conclusion that the slides likely occurred in wetter times during the Pleistocene? Wetter Pleistocene could have been the condition at the site only about 12,000 years ago and may be relevant to the next 1,000 years projection. Are there analogous site(s) along Book Cliffs that have known high or higher (and/or low or lower) rates of slumping hazards similar to those at Crescent Junction?

Response:
In most of arid to semi-arid Utah, it has been recognized that most landslides are presently inactive, or they become active only during periods of extremely high amounts of precipitation. Times of glaciation during the Pleistocene were during a climate of much lower temperatures and much larger amounts of precipitation than at present and were favorable for the formation of landslides (Shroder 1971). The landslides north of the site in the Book Cliffs were likely active during the most recent glacial episode in the late Pleistocene, and they may have formed then or during earlier glacial episodes in the Pleistocene. This reference on landslides in Utah by Shroder (1971) and additional discussion are included in the revised calculation set for Photogeologic Interpretation (RAP Attachment 2, Appendix G).

G6. Geomorphology: Explain the origin and age of the pediment-mantling deposits and surfaces located near the site.

Attachment 2, Appendix B, page 7, Section 2.5, discusses the "pediment-mantling deposits" reported by the applicant. Has DOE considered that these deposits might be indicative of former, uplifted pediments? If they are tectonic- geomorphic features, what clues do they provide to rates of erosion, episodes of differential uplift, possibly faulting? If the surfaces are tectonic-geomorphic in nature, is the age of the surfaces known, or is it possible to determine the approximate age, and if tectonic activity produced the surfaces, is this significant to the design of the disposal cell?

Response:
The origin of the pediment-mantling deposits is discussed in the revised calculation set for Site and Regional Geomorphology – Results of Literature Research (RAP Attachment 2, Appendix C). Intact pediments mantled by alluvial material are west of the withdrawal area and represent alluvial deposits from the ancestral Crescent Wash. No evidence for fault displacement has been seen around the pediments to indicate they have been uplifted. The location and characteristics of the mantled pediment surfaces are consistent with their origin as alluvial deposits from ancestral drainages from the Book Cliffs that were preserved as pediment mantles after stream capture by drainages in Mancos Shale. It is possible that a new mantled pediment surface could start to form after an estimated 1,600 years after capture of Crescent Wash by incisional headcutting of the West Branch of Kendall Wash, as described in the revised calculation set for Site and Regional Geomorphology – Results of Site Investigations (RAP Attachment 2, Appendix D). This erosional process, if it occurred, is far enough away to the west to not affect the disposal cell.

G7. Mining, Oil & Gas: Discuss current or past mining, mineral, and oil and gas claims for the site or within a radius near the site that have similar geologic characteristics.

RASR, page 3-4, section 3.4. The statement is made that "Pockets of natural gas were encountered during the drilling conducted as part of this project. Commercial exploration for oil and gas has been, and continues to be, common in the Crescent Flat area." Also, many boreholes are noted on the USGS quadrangle as well as mining pits. Is there a possibility that this site could cause a conflict with future mining claims?

Response:
An expanded discussion of oil and gas resources and exploration in the site area is in the revised calculation set for Site and Regional Geology – Results of Literature Research (RAP Attachment 2, Appendix A). In that calculation set, it is stated that the withdrawal area is leased for oil and gas, and that surface exploration would not be prohibited from the area, except for the disposal cell (approximately 250 acres). Directional drilling would allow the area under the disposal cell to be explored. No active mining claims are in the withdrawal area, and the establishment of the withdrawal area precluded new mining claim locations. After the disposal cell is constructed, most of the withdrawal area will be released, and mining claim locations will be allowed. As noted in the revised calculation set for Photogeologic Interpretation (RAP Attachment 2, Appendix G), the pits southeast of the withdrawal area along old U.S. Highway 50, initially thought to have been made for gold exploration, were actually made for exploration for road metal for highway construction.

G8. Mining, Oil & Gas: Discuss past mining, mineral, and oil and gas activities that may have occurred at the site.

Attachment 2, Appendix A, Resource Development, page. 5, para 1. This section refers to a petroleum accumulation 3 mi SSW, without extrapolating the potential significance. However, there is an oil accumulation about 3 mi WNW of the site that is not mentioned. It is not known if this play is in the Mancos or deeper (reference is a booklet on Grand County geology by Utah Geol Survey dated 1987). The statement is made, "Data concerning the targeted gas horizons and the actual results of this exploration are not currently available. When will additional data be obtained on oil and gas targets in the site vicinity and on pressurized gas pockets? This may bear on potential future disruptive activities that may be safety related.

Has DOE checked for past drilling activities at the proposed site? Old drill sites and improperly abandoned drill-holes may provide a pathway for water and transient drainage from the cell to impact groundwater. Geophysical survey logs, borehole logs, geological descriptions and cross sections may be available for the site area. Also, driller's reports of subsurface conditions such as groundwater, brines, pressurized gas, deformable holes and other information may be available.

Response:
Discussion of oil and gas resources for the withdrawal area and nearby surrounding area was expanded in the revised calculation set for Site and Regional Geology – Results of Literature Research (RAP Attachment 2, Appendix A). Included in the revision is information on oil and gas wells and fields from the Oil and Gas Fields Map of Utah (Chidsey et al. 2004), the Utah Division of Oil, Gas and Mining oil and gas information website, the Mineral Potential Report for the BLM Moab Planning Area (Tabet 2005), and the Mineral Report by the BLM on the DOE Proposed Disposal Site (Bain 2005).

G9. Seismology: Describe the association of the earthquakes that are located close to the Little Grand Fault No. 9 and the proposed site. Examine the possibility that the two earthquakes in the vicinity of the Little Grand Fault may have resulted from movement on this fault.

Attachment 2, Appendix F, Figure 7, page 13. There are earthquakes located very close to Fault No. 9. Does Fault No. 9 have a bearing as to the design earthquake for the site? Earthquake locations are not known accurately due to lack of instrumentations in the vicinity of the site. Provide good evidence that the Little Grand Fault is not capable.

Response:
The two events in question are a July 30, 1953, event with an estimated intensity of 5, and a March 31, 1954, event with an estimated intensity of 4. Both events are cataloged as non-instrumental events in the Catalog of Earthquakes Occurring in the Eastern, Central, and Mountain States of the United States, 1534-1986 [SRA (Stover, C.W., G. Reagor, and S.T. Algermissen, 1984, United States earthquake data file: U.S. Geological Survey Open-File Report 84-225.)].

Epicenter accuracy for both events is estimated to be within 0.5 to 1 degree, or approximately 30 to 60 mi (SRA). The source for the catalog comes from the University of Utah Seismograph Station (Arabasz et. al, 1979). In this earthquake listing, non-instrumental epicenters are assigned coordinates corresponding to the location of the town or city where the felt effects were strongest. In this case, the coordinates were assigned to the location of the town of Green River. Therefore, the earthquake location is fairly uncertain, and in actuality could have occurred at any location within 30 to 60 mi of Green River. Due to the low magnitude of the events (estimated by converting intensity to Richter magnitude) of 4.3 and 3.7, respectively, it is unlikely that either of these events would result in a surface rupture. Therefore, it is unlikely that the true location of these events could be better estimated by field evidence.

The capability of the Little Grand Fault (earlier referred to as the Little Grand Wash Fault) was evaluated during the seismotectonic study performed for the Green River Site, as discussed in the calculation set for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E, page 14). Based on the lack of offset in the alluvial, colluvial, and talus materials overlying the fault, it was concluded during that study that the fault is not capable. Later mapping of the fault (Chitwood, J.P., 1994.

Provisional Geologic Map of the Hatch Mesa Quadrangle, Grand County, Utah, Utah Geological Survey, Map 152, scale 1:24,000), (Doelling, H.H., 2001. *Geologic Map of the Moab and Eastern Part of the San Rafael Desert 30' × 60' Quadrangles, Grand and Emery Counties, Utah, and Mesa County, Colorado,* Utah Geological Survey Map 180, scale 1:100,000) also did not observe any offset of Quaternary deposits.

Further capability of the Little Grand Fault was also evaluated in April 2007 to specifically examine the eastern portion of this fault that is closest to the site. South of the Green River, Utah, Site, displacement on the Little Grand Fault is more than 500 ft. Displacement on this easterly-striking normal fault (down to the south) decreases eastward. The fault was checked for evidence of Quaternary movement for approximately 6.5 miles along its eastern part (using mapping mainly by Doelling [2001] and Chitwood [1994]), starting where the fault passes under old U.S. Highway 50 in the SE¼ Section 27, T.21S., R.17E. The fault becomes less distinct eastward through Green River Gap (where displacement is only a few tens of feet) and to the easternmost place where it is recognized by Chitwood (1994) along the left fork (or west branch) of Floy Wash in the SE¼ Section 22, T.21S., R.18E. In places along the fault where it is overlain by Quaternary pediment-mantling material or terrace gravels, no displacement of these units was seen. Based on this traverse of the eastern part of the Little Grand Fault, it is concluded from the lack of Quaternary displacement that the fault is not capable.

The information above has been included in revised calculation sets for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration (RAP Attachment 2, Appendix F) and for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E).

G10. Seismology: Explain why some faults that show no evidence of Quaternary faulting are considered capable while others are not.

Attachment 2, Appendix F, Table 3, page 16. Table 3 indicates that Fault No. 7 shows no evidence of Quaternary faulting, but it is considered as a potential design fault. Meanwhile, Faults 4, 5, and 6 also do not show Quaternary faulting but they are not potential design faults. Please provide appropriate rationale to explain this discrepancy.

Response:
Discussion as to the capability of these faults based on literature review is discussed in the revised calculation set for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E, p.14). In this discussion, it is explained that unnamed faults 1, 2, and 3 are all of similar strike and appear to be features related to salt subsidence related to the Thompson Anticline. Faults 1 and 2 were investigated in 2005 and showed no sign of Quaternary movement. By association, fault 3 is assumed to also be related to subsidence of the Thompson Anticline. It was concluded that there is sufficient evidence to suggest faults 1, 2, and 3 are not active, and therefore not potential design faults. Unnamed faults 4, 5, and 6 appear to be splays of the Salt Valley Anticline. As discussed on page 9 of the calculation set, there is sufficient evidence to suggest these faults are related to dissolution and collapse of the Salt Valley Anticline, are not active, and therefore are not potential design faults.

Fault 7 is unique from the other unnamed faults in that it does not appear to be related to salt subsidence. The likely age of disturbance is between Late Cretaceous and early Eocene and there is no known Quaternary displacement on this fault. However, the age of faulting has not been substantially documented in literature, nor has it been field verified.

Therefore, it has been conservatively assumed that this fault, due to lack of thorough investigation, will be considered a potential design fault. This consideration has negligible impact on the seismotectonic characterization of the site, as the peak horizontal acceleration (PHA) estimated for fault 7 of 0.13g is below the recommended design PHA of 0.22g.

G11. Geology: Discuss additional field work that has taken place to confirm or deny the existence of faults.

Attachment 2, Appendix A, Structural Setting, page 5, para. 2. The statement is made, "Surface field work and an additional search for well data in the area will be undertaken to confirm or deny the existence of the fault." Clearly indicate what additional field work has taken place and document the findings.

Response:
No surface evidence of a northeast-striking fault was found in the southwest corner of the withdrawal area during field work in April 2006. The existence of a fault in that area had been inferred from differences in depths to the base of the Mancos Shale found in two nearby oil test wells drilled in the 1920s. The surface location of only one of the old test wells has been found. Results of the search for this fault and any other faults in the withdrawal area are in the revised calculation set for Surficial and Bedrock Geology of the Crescent Junction Disposal Site (RAP Attachment 2, Appendix B).

G12. Geology: Explain the origin of the fault associated with the axis of the Thompson

Anticline and why this fault shows up to 90 ft of displacement in some locations but no apparent displacement of the Mancos.

Attachment 2, Appendix G, low sun-angle photographs (e.), page 4. Potential fault. The graben strikes N20W and is located 2 miles from withdrawal area, at Thompson Anticline. One fault shows displacement of up to 90 ft. No displacement of these faults is discerned at contact with Mancos. There is no additional evidence to support that no displacement has occurred at the contact with the Mancos. Clearly identify this fault on the seismic map and explain why there is no apparent displacement in underlying Mancos. How small a displacement could have been detected given the methods used?

Response:
The origin of the faults along the axis of the Thompson Anticline is discussed in the revised calculation set for Site and Regional Geology – Results of Literature Research (RAP Attachment 2, Appendix A) and the revised calculation set for Site and Regional Seismicity – Results of Literature Research (RAP Attachment 2, Appendix E). An investigation of faults in the area was conducted in November 2005. Displacement of the resistant sandstone beds of the Blackhawk Formation and Castlegate Sandstone that cap the Book Cliffs is well exposed along the faults, but displacement (even though it apparently occurs) in the underlying soft and mostly talus-covered Mancos Shale is not exposed. This observation is in the revised calculation set for Photogeologic Interpretation (RAP Attachment 2, Appendix G).

G13. Geology: Discuss the two pediment remnants near the site identified by DOE that are vertically offset.

Attachment 2, Appendix G, Low sun-angle photographs (g), page 5. A potential fault has been identified by DOE. Two pediment remnants are vertically offset about 45 ± 5 ft, center of Sec 33. It is uncertain whether the surfaces are two different pediment surfaces or is the same surface that is faulted. If it's a fault, it appears to be young and is close to the site and could be a capable fault. This potential fault warrants further assessment.

Response:
See Response for 8, in relation to area "g", in the NRC Comments and DOE Responses for the April 2006 Meeting.

G14. Geology: Investigate the linear feature striking N 70 E that appears on the Plate 1 aerial photograph extending from Horse Heaven to the northeast and through Crescent Wash to the southwest.

This linear feature is not noted by DOE in the RASR. However, it was noted and discussed by NRC staff during the site visit in December 2006. Additional field investigation should be considered to determine if there is any evidence that this feature is a fault, and if so, if it is capable.

Response:
Characteristics of the N70E-trending linear feature were investigated in March 2007 and are discussed in the revised calculation set for Photogeologic Interpretation (RAP Attachment 2, Appendix G). No evidence for faulting was seen along the length of the

feature from Crescent Wash to the south part of Horse Heaven. A prominent joint system in the Blackhawk Formation strikes approximately the same direction as the trend of the linear feature, and several parallel rotational slump blocks in the south part of Horse Heaven trend in a similar direction. It was concluded that the linear feature is an expression of the prominent joint system, which is important for landslide erosion on the north side of the Book Cliffs, but will not affect the disposal site area.

G15. Seismology: Provide the basis for choosing the parameter values, in Attachment 1,

Appendix D, Liquefaction Analysis, for water content, type of sand (clean/silty), and relative density, and provide their uncertainties. Provide the necessary justification for using Fig. 11.8 mentioned in the calculations, although the design earthquake for the site is less than that mentioned in the figure.

Justification for the parameter values was not provided. Changes in these parameters may change the condition of the layer from being non-liquefiable to being liquefiable.

Response:
The calculation for Settlement, Cracking, and Liquefaction Analysis (RAP Attachment 1, Appendix D) has been updated to reflect tailings test results. The key tailings parameters used in the liquefaction analyses were compacted unit weight and fines percentage (derived from the tailings testing). The unit weight representing compaction to 90 percent of Standard Proctor density (50 percent relative density) was used, and fines percentages representing the minimum and mean measured values were used.

The calculation set for Settlement, Cracking, and Liquefaction Analysis (RAP Attachment 1, Appendix D) was revised, and changes were made to text in RAS Section 4.2.2.

Geotechnical Stability

GT1. Characterization of Site Stratigraphy and Tailings: DOE and Golder Associates have indicated several data quality issues with test data from the laboratory used for geotechnical testing. As examples, there are questions on permeability test inconsistencies (Attachment 5, Appendix K), and there are several open comments on data quality from a Golder letter dated March 23, 2006 (Attachment 5, Appendix J). Provide a list of all unresolved issues with the test data quality and discuss the status of resolution of each of the issues.

Response:
All issues pertaining to test data quality have been resolved in revised calculation sets that were completed for the draft final RAP.

With regard to the calculation set for Supplemental Geotechnical Properties of Native Materials (RAP Attachment 5, Appendix K): Data quality checks of the original laboratory data revealed that retests would be needed for the triaxial compressive strength and hydraulic conductivity analyses of sample number 154 at 20 ft. Laboratory results of this retest are presented in Appendix C of this revised calculation.

In addition, data quality checks also indicated that retests of hydraulic conductivity would be required for sample numbers 152 at 23 ft, 154 at 12 ft, and 156 at 12 ft. Laboratory results of these retests are contained in Appendix D of this revised calculation. With the completion of the triaxial and hydraulic conductivity retests, which are documented in Appendixes C and D of this revised calculation, all data quality deficiencies associated with the original calculation were resolved.

With regard to the calculation set for Geotechnical Laboratory Testing Results for the Moab Processing Site (RAP Attachment 5, Appendix J): On August 16, 2006, the laboratory responded to the comments in Golder Associates' March 23, 2006, letter. In conjunction with their response, the laboratory issued page changes to the May 3, 2006, *Certificate of Analysis*. These page changes were inserted into both the electronic version of the May 3, 2006, data set and the paper copies of that data set.

During QA verification of the final data set, S.M. Stoller discovered one remaining error in the May 3, 2006, *Certificate of Analysis*. In a letter dated February 21, 2007, the laboratory responded and sent one additional page change to the May 3, 2006, data set. With the inserted page changes, the data contained in the May 3, 2006, *Certificate of Analysis* is now deemed to be complete and validated. No additional action is required. Appendix C contains, in chronologic order, each of the letters that were generated during the data review process. Page changes issued by the laboratory are included in the May 3, 2006, *Certificate of Analysis*, which is contained in Appendix B of this calculation.

GT2. Characterization of Site Stratigraphy and Tailings: In Section 4.1.2 of the Remedial Action Selection Report, DOE indicates that all of the materials that will be used in construction of the disposal cell cover will be obtained from the cell excavation. Based on the boreholes and test pits conducted at the disposal site, provide representative cross sections of the Quaternary materials and weathered Mancos Shale. Using these cross sections, provide estimates of the volumes of materials available from the excavation and a demonstration that the volumes will be adequate to construct both Alternative covers being considered without the need for additional borrow areas.

Response:
Section locations and cross sections are provided in Section 7 of the RAS as part of the response to Comment G4. The disposal cell layout has been based on a capacity for 12 million cubic yards (yd^3) of residual radioactive material (RRM). The objective of the excavation and cell construction was to achieve a balanced cut-and-fill, subject to the constraint that the height of the tailings above adjacent ground would be minimized while the base of the disposal cell would be cited beneath the top of the weathered Mancos Shale. All of the excavated material is intended to be used for cell-construction. Excess excavated material (if produced) will be placed on the top of the disposal cell as additional cover material or on the side slopes as additional embankment material.

The cell will be excavated into weathered Mancos Shale, with an anticipated average depth of excavation of 16 ft. This excavation will provide approximately 3.4 million yd^3 of Quaternary alluvial and colluvial soils and approximately 1.7 million yd^3 of weathered

Mancos Shale. This excavated material will be used to construct the perimeter embankment and cover for the disposal cell. For this cell layout, the required embankment volume is approximately 1.2 million yd^3. The required volume for the UMTRA Project cover is approximately 2.9 million yd^3, and the required volume for the Alternative cover is approximately 3.6 million yd^3. Assuming an average of 13 to 15 percent shrinkage for the two cover systems, the excavation produces approximately the quantity required for cover and dike construction.

The following three tables summarize the estimated amounts of material to be excavated within the footprint of the disposal cell, along with approximate material requirements for the two proposed cover alternatives.

Table 1. Materials Excavated from Within Disposal Cell Footprint

Material	Volume (million yd^3)
Quaternary alluvium	3.42
Weathered Mancos Shale	1.69
Total cut material	5.11

Table 2. Materials Required for Disposal Cell Construction (UMTRA Project Cover)

Material	Volume (million yd^3)
Berm (Quaternary alluvium and weathered Mancos Shale)	1.24
3.9 ft of Radon Barrier (weathered Mancos Shale)	1.29
3.0 ft of Frost Protection (Quaternary alluvium and weathered Mancos Shale)	0.99
1.0 ft of Interim Cover (Quaternary alluvium and weathered Mancos Shale)	0.33
Net Excess cut (Quaternary alluvium and weathered Mancos Shale)	1.26
Net Excess cut (Quaternary alluvium and weathered Mancos Shale) accounting for 15 percent shrinkage with compaction	0.49

Note: Rock-Mulch Barrier and Infiltration and Barrier account for 0.17 million yd^3 each and are derived from off-site borrow sources.

Table 3. Materials Required for Disposal Cell Construction (Alternative Cover)

Material	Volume (million yd^3)
Berm (Quaternary alluvium and weathered Mancos Shale)	1.24
8.8 ft of Monolithic Cover (Quaternary alluvium and weathered Mancos Shale)	2.91
1.0 ft of Interim Cover (Quaternary alluvium and weathered Mancos Shale)	0.33
Net Excess cut (Quaternary alluvium and weathered Mancos Shale)	0.61
Net Excess cut (Quaternary alluvium and weathered Mancos Shale) accounting for 8 percent shrinkage with compaction	0.25

Note: Rock-Mulch Barrier and Infiltration and Barrier account for 0.17 million yd3 each and are derived from off-site borrow sources.

GT3. Characterization of Site Stratigraphy and Tailings: In Section 2.5 of the Remedial Action Selection Report, DOE indicates that the presence of swelling clays in the Mancos Shale is a potential geologic hazard. Provide discussion of the samples tested and the corresponding test results that demonstrate that swelling clays will not be a problem at the Crescent Junction Disposal Cell.

Response:
Swelling clays are a component of the Mancos Shale in the western U.S., and are a geologic hazard in terms of volume change from variations in water content. This is not a factor at the base of the disposal cell (where variations in water content are not expected). In the disposal cell cover, variations in water content should be accommodated within the frost-protection zone of the cover.

In general, a plasticity index greater than 15 can be an indication of highly swelling clays (International Building Code, 2003. Section 1802.3.2, International Code Council, Country Club Hills, Illinois). The average plasticity index of the weathered Mancos Shale is 11 (Geotechnical Properties of Native Materials, RAP Attachment 5, Appendix E). Therefore, the weathered Mancos Shale is likely to be slightly to moderately expansive in the area of the disposal cell, which can be accommodated in the design of disposal cell.

GT4. Slope Stability: In general, the various analyses make it unclear what exactly the cover and clean-fill dike are composed of. The slope stability analyses were performed using only the Alternative Cover. In the Remedial Action Selection Report (Figure 5.1), DOE indicates that the cover is composed of a mixture of "slopewash, eolian soils, and weathered Mancos Shale." The slope stability analysis considers the cover (radon barrier) to be composed of only "sheet wash and eolian soils" (Attachment 1, Appendix C, Table 1). There is a similar discrepancy for the clean-fill dike. Table 1 of the slope stability analysis shows the clean-fill dike material to be recompacted "weathered Mancos Shale," while Attachment 1, Appendix C, page 7, describes the clean-fill dike as "recompacted weathered Mancos Shale, alluvial, and eolian soils." Provide clarification of these discrepancies and discussion of any resulting impact on the slope stability analyses.

Response:
The perimeter embankment (clean-fill dike) and cover will be constructed from the material excavated from within the footprint of the disposal cell, consisting of Quaternary alluvial, colluvial, and eolian soils and weathered Mancos Shale. The only segregation of these materials will be for construction of the radon barrier, where weathered Mancos Shale will be used. The rest of the structures will be constructed with a mixture of these excavated materials. This composition of materials is represented in the revised calculation for Slope Stability of Crescent Junction Disposal Cell (RAP Attachment 1, Appendix C).

GT5. Settlement: Include additional information as part of the settlement analysis presented in

Attachment 1, Appendix D. Provide a tabulation of the material layers considered in the analysis, references to the tests performed (or other basis) to determine each layer's settlement analysis parameters, and the resulting engineering parameters. Also provide a description or figure indicating the locations chosen for settlement analysis to demonstrate that the worst, average, and best settlement conditions have been selected and the largest differential settlement conditions have been analyzed.

Response:
The calculation set for Settlement, Cracking, and Liquefaction Analysis (RAP Attachment 1, Appendix D) has been updated to incorporate tailings-consolidation test results. Settlement analysis calculations were conducted for the largest anticipated tailings thickness (38 ft) and the largest anticipated thickness of cover and interim cover (13 ft). Settlement was analyzed at approximately the 1/3 and 2/3 depths within the tailings profile, and added to provide estimated total settlement of 1 ft or less (for primary settlement).

For differential settlement, the location within the disposal cell anticipated to have the highest potential for differential settlement is along the perimeter of the inside of the disposal cell, where the tailings thickness varies from 38 ft to zero over a distance of 76 ft. Other areas of tailings within the disposal cell would not the have the tailings thickness variation as along the cell perimeter, and would be spread in lifts and compacted.

GT6. Settlement: In Section 4.2.2 of the Remedial Action Selection Report, DOE indicates that settlement will be low due to the methods of mixing, placement, and compaction of the tailings in relocating the contaminated material to the Crescent Junction Disposal Cell. Provide additional description of the procedures for bringing the excavated wet tailings to optimum moisture at placement and compaction.

Response:
Initially upon excavation from the Moab tailings pile, the moisture content of the slime tailings is likely to exceed optimum conditions for compaction. Excavated slime tailings will therefore be mixed at the Moab site with the drier sand tailings. Mechanical mixing will yield an average water content that is appropriate for the transportation technique selected by the remedial action contractor. The transported tailings will be placed in the disposal cell and processed by the following procedure: (1) dumping from trucks along a working face or specific area, (2) spreading in lifts with a dozer, and (3) compacting the spread lift of tailings with a compactor. Water will be added as necessary (by spraying) for dust suppression. From this process, the tailings should be near optimum water-content conditions during compaction in the cell.

GT7. Settlement: Provide a discussion of whether or not there are plans for monitoring settlement during and following construction of the disposal cell. If there are plans, provide details of the monitoring plan; if there are no plans, provide the basis for not monitoring.

Response:
Because the tailings will be placed, spread, and compacted in the disposal cell in lifts, with significant time between tailings placement and cover construction, significant tailings settlement is not anticipated. Monitoring of settlement of the cover surface is planned for

confirmation of cell performance, by monitoring of settlement plates or survey monuments.

GT8. Cover Design: In Section 5.0 and Figure 5-1, DOE discusses and portrays two different cover alternatives, but does not indicate which is planned or preferred. Provide a discussion on the factors that will determine which of the two covers will be used.

Response:
Both cover alternatives will meet the appropriate performance standards in 10CFR192 and NRC guidance. Selection of the cover alternative will be based on permitting and construction costs.

GT9. Cover Design: In its settlement analysis (Attachment 1, Appendix D), DOE analyzes settlement and cracking for only the UMTRCA cover. In its slope stability analysis (Attachment 1, Appendix C), DOE only analyzes the stability with the Alternative cover. Provide a discussion of why different covers are used from analysis to analysis and how the analyses presented conservatively band both covers being considered.

Response:
The UMTRCA cover was analyzed for settlement and cracking because of the compacted clay radon barrier in the cover system. Settlement and cracking of the Alternative cover is not as critical for cover system performance due to the increased thickness of the total cover and the lower level of compaction effort during construction. The Alternative cover was used in the slope stability analysis because it represents the thickest cover configuration and, therefore, the highest slope heights. However, the UMTRCA cover has been conservatively analyzed by changing the properties of the cover to represent the compacted clay properties of the weathered Mancos Shale. The actual UMTRCA cover consists of several layers, but the compacted clay represents the weakest of those layers. The calculation set for Slope Stability of the Crescent Junction Disposal Cell (RAP Attachment 1, Appendix C) has been updated to include these analyses. The computed factors of safety are similar to the Alternative cover analysis. Critical failure surfaces pass predominately through the perimeter embankment. Therefore, the stability of the disposal cell is relatively insensitive to cover-material thickness, and to the shear strength of the cover material and compacted tailings.

GT10. Cover Design: In Section 4.1.2 of the Remedial Action Selection Report, regarding the potential for "bathtubbing", DOE indicates that the excavation will be into the weathered Mancos Shale, which has hydraulic conductivities of from 10^{-4} to 10^{-3} cm/sec. Elsewhere, DOE estimates the hydraulic conductivity of the cover to be 7×10^{-5} cm/sec. Discuss the basis for concluding that both of the covers being considered have conductivities as low as $7\text{x}10^{-5}$ cm/sec. In addition, discuss the potential for the cell excavation to extend to a depth that removes most of the weathered Mancos Shale, and thus result in a base conductivity much less than the assumed 10^{-4} cm/sec.

Response:

Excavation for the disposal cell is anticipated to average approximately 16 ft, which results in the removal of alluvial/colluvial materials and notching the base of the disposal cell below the surface of the weathered Mancos Shale. The weathered Mancos Shale transitions into unweathered Mancos Shale, with minimal fracturing, at depths of 60 to 80 ft below the original ground surface. Because the base of the disposal cell will be in the uppermost weathered Mancos Shale, the thickness of the weathered Mancos Shale beneath the disposal cell will be approximately 40 to 60 ft.

The key parameter for the evaluation of bathtubbing is not the hydraulic conductivity of the cover, but the net rate of infiltration through the cover. The net infiltration is dictated by the hydraulic conductivity of the cover materials as well as the thickness and water-holding capacity of cover materials to retain moisture for evapotranspiration. After the onset of steady-state drainage conditions, the net infiltration rate for both Alternative and UMTRA covers is conservatively estimated to be on the order of 1×10^{-7} cm/sec (or 0.1 ft/year).

The potential for bathtubbing as well as the potential for tailings leachate to migrate laterally and enter nearby gullies and washes is evaluated below. The key stratigraphic zones are summarized in the following table.

Zone	Approximate Thickness (ft)	Hydraulic Conductivity or Flux Rate	
		(cm/sec)	(ft/yr)
Cover	9-11	1.0×10^{-7}	0.1
RRM	35-45	3.0×10^{-5}	30
Weathered Mancos Shale	40-60	2.1×10^{-3}	2100
Unweathered Mancos Shale	2,400	3.6×10^{-8}	0.036

Because the influx of meteoric water is controlled by the design flux through the cover, meteoric water could migrate downward at an average rate of 0.1 ft/year (RAP Attachment 3, Appendix G). Steady-state infiltration through the cover would occur as unsaturated flow and gradually penetrate down to the top of the unweathered Mancos Shale. Inasmuch as the hydraulic conductivities of the RRM and the unweathered Mancos Shale are larger than the design flux through the cover, conservative assumptions indicate that the resulting downward flow could pass through the entire stratigraphic sequence and build up a zone of saturation at the top of the unweathered Mancos Shale, where the flux (at a unit gradient) would be a factor of 2.8 smaller than 0.1 ft/year.

The downward movement of meteoric water through this stratigraphic column is explained in terms of a simple water balance. For a flux of 0.1 ft/yr, the flow through the 250-acre disposal cell is approximately 1.09 million ft^3/yr [15.5 gallons per minute (gpm)]. The downward flux (at a unit gradient) into the unweathered Mancos Shale is conservatively 0.036 ft/yr or approximately 0.39 million ft^3/yr (5.6 gpm) over the area of the disposal cell.

Therefore, approximately 0.70 million ft^3/yr (9.9 gpm) could migrate laterally away from the perimeter of the disposal cell footprint.

The leachate would eventually be consumed by slow vertical leakage into the unweathered Mancos Shale (RAP Attachment 3, Appendix G). If more realistic assumptions are considered, there is no potential for mounding or lateral spreading to occur in the weathered bedrock. Regardless of the assumptions that are considered, there is very little risk of potential discharge of leachate into surface drainages.

Surface Water Hydrology and Erosion Protection

SW1. Design of Erosion Protection for North Diversion Channel: The RAP indicates that riprap will be provided for the north slope of the disposal cell and the left side of the diversion channel and that the rock will be designed to protect against velocities produced by the PMF in the channel. However, it appears that the design of the riprap may also need to be based on velocities and shear stresses that will occur in gullies that discharge into the diversion channel. It appears that a significant number of gullies have formed and will discharge into the diversion channel in an unpredictable manner. The staff concludes that these gullies are likely to produce the design condition for the rock in the channel.

Staff review of the RAP indicates that DOE computed the scour depth, using assumptions associated with flows occurring perpendicular to the diversion channel, and the staff concludes that DOE'S assumptions related to gully size and discharge are appropriately conservative. However, the size of the riprap should also be based on similar assumptions. It is likely that the flow velocities occurring in these gullies will exceed the velocities in the diversion channel, thus requiring larger riprap sizes. In addition, the proposed rock cutoff wall and/or rock toes should be designed for the gully velocities, and the size and volume of rock should be adjusted accordingly.

DOE should either revise the design to account for velocities in the gullies, or provide additional justification for the current design.

Response:
The riprap along the base of the channel will have a median rock size of 20 inches to resist flow velocities from gullies discharging into the diversion channel. The riprap will be placed in adequate volume to act as self-launching riprap that will fill in scour holes to the maximum predicted scour depth. This modification has been made to the calculation set for Diversion Channel Design, North Side Disposal Cell (RAP Attachment 1, Appendix G).

SW2. Design of Riprap for the Diversion Channel Outlet: Staff review of the design of the riprap for the diversion channel outlet indicates that the rock size and volume may not be adequate to prevent head-cutting and gully intrusion into the channel. The assumptions related to flow distribution across the outlet structure do not appear to account for localized flow concentrations. Further, the volume of the rock provided does not appear to be adequate to fill in scoured areas during the occurrence of major floods.

During the December site visit, the staff observed significant gullies downstream of the site, relatively close to the southwest corner of the proposed cell. Because the drainage area to this area will be increased by diverting flows in the diversion channel, there is a significant potential for large gullies to form and migrate upstream toward the disposal cell.

The design condition for computing the rock size and volume should be based on assumed areas of flow concentrations occurring downstream of the outlet structure. The velocities in these areas of flow concentration should then be used to compute the scour depth, rock size, and rock volume, based on collapse of the rock structure on a slope of about 1V on 2H. It is relatively obvious that flows occurring on the steep 1V on 2H collapsed slope will likely result in very large rock sizes. Alternately, DOE could provide a design where the downstream slope of the structure is constructed on a pre-formed specific slope, such as 1V on I0H, thus reducing the rock size requirements.

DOE should revise the design or provide additional justification that the design is adequate to prevent head-cutting into the diversion channel. If DOE chooses to make revisions, the design of the outlet for this diversion channel could be similar to other Title I designs that have been previously approved. Guidance may also be found in NUREG-1623.

Response:
The outlet structure has been modified to include a pre-formed, 1V:10H, buried rock structure excavated to the maximum predicted scour depth. This modification has been made to the calculation set for Diversion Channel Design, North Side Disposal Cell (RAP Attachment 1, Appendix G).

SW3. Design of West Slope and Toe of Disposal Cell: Based on observations of on-site gullies during the site visit, the staff considers that flows discharging from the currently-proposed location of the diversion channel outlet could potentially erode the west side slope and/or toe of the disposal cell. Based on the size, depth, and relative closeness of the existing gullies immediately downstream of the southwest corner of the proposed cell, it appears that gullies of similar size and depth could form immediately adjacent to the toe and could erode to a depth that could undercut the rock toe.

DOE should revise the design of the west slope and toe of the disposal cell by: (1) increasing the rock size and volume of the toe; (2) extending the outlet of the diversion to the west so that the west side slope of the cell is not affected; or (3) changing the footprint and alignment of the west side of the cell.

Response:
The outlet of the diversion channel has been extended westward to minimize impacts on the west side slope of the cell. This modification has been made to the calculation set for Diversion Channel Design, North Side Disposal Cell (RAP Attachment 1, Appendix G).

SW4. Delineation of Competent Mancos Shale: On page 5 of Appendix G, DOE indicates that riprap will extend to the computed scour depth or to where competent Mancos Shale is encountered. In general, the staff considers that many Mancos Shale formations may not be extremely hard or durable if exposed to weathering. If riprap is keyed into such formations, erosion and loss of rock volume could occur. Further, during the site visit where the test pit was observed, the staff did not observe any competent shale layers that would provide suitable protection if exposed by erosion.

DOE should provide a clear description and definition of what will be done to determine the competency of Mancos Shale in those areas where riprap will be extended below grade or where erosion is expected to occur. Alternately, DOE could provide rock of sufficient volume to extend to the expected depth of scour.

Response:
DOE has selected the alternate approach; riprap volumes have been increased such that the rock will extend to the expected depth of scour. The riprap will not be keyed into the Mancos Shale. This modification has been made to the calculation set for Diversion Channel Design, North Side Disposal Cell (RAP Attachment 1, Appendix G).

SW5. QA/QC Procedures for Rock Production: Based on observations made during the December site visit, it appears that the rock in either of the proposed quarries is somewhat variable, depending on the location where rock will be produced within the quarry. DOE should provide additional information to document the quality assurance and quality control (QA/QC) procedures that will be implemented during rock production at the quarries to address this variability and to assure that rock of acceptable quality will consistently be produced. DOE should discuss how acceptable rock will be identified and unacceptable rock avoided as part of the QA/QC procedures for rock production.

DOE should describe the lithologic variability of the rock sources and identify features adverse to rock durability and resistance to weathering. Variability is also the basis for selecting representative samples for durability tests and petrographic analysis. Discuss how representative samples were obtained. Potential features could include mudstone/clay interbeds, conglomerate/calcrete beds, bedding planes, or fractures that could be vulnerabilities to freeze thaw and reduction in rock size. Explain how the mudstones and limestones above and below the sandstone will be able to be avoided in producing the sandstone.

Petrographic analysis, together with published literature, should be used to identify the minerals and percentages. Petrographic analysis should clearly identify the rock source of the sample. Mineralogy of the sandstone cement should be identified and the type of clays, if present.

In addressing the above items, consider the sedimentologic, stratagraphic, and petrologic analysis given in Currie, Brian S. "Upper Jurassic-Lower Cretaceous Morrison, and Cedar Mountain Formations, NE Utah-NW Colorado: Relationships between Nonmarine

Deposition and Early Cordilleran Foreland-Basin Development", Journal of Sedimentary Research, Vol. 68, No. 4, July 1998.

Response:
The selected rock for use as erosion-protection material will be assessed in two phases. The first phase will be evaluation of the potential rock quarries from testing of representative rock samples from each quarry for durability. Rock quality designation values will be calculated using the test methods for rock type outlined in NUREG-1623. Testing will include petrographic analyses, with specific emphasis on bedding planes and fracturing, as well as the presence of clay minerals or soluble minerals. The results of the first phase will be determination of rock quarries that can produce acceptable rock for erosion protection.

The actual rock quarry to be used will be selected from the quarries that can produce acceptable erosion-protection material based on production and transportation cost, production schedule, material variability, and other factors. The second phase of evaluation will be confirmation that rock from the selected quarry will meet required durability requirements and particle-size distribution specifications. This evaluation will consist of testing of rock samples produced from the selected quarry either at the quarry or as delivered to the disposal cell site. The frequency of testing is usually based on a test per ton or cubic yard of rock, and is structured to represent rock production from startup to completion of operations. Rock not meeting the durability or particle-size requirements during this second phase of evaluation will be rejected.

Water Resources Protection

GW1. Discuss how tailings drainage will be confined to the weathered and unweathered Mancos Shale and be precluded from seeping along the contact between the weathered Mancos Shale and the overlying unconsolidated Alluvial/colluvial material and possibly migrating offsite.

RASR (Remedial Action Selection Report), page 2-7, section 2.3.2. There is NRC interest in the contact between the weathered Mancos and the overlying alluvial sediments to determine if this contact could provide a pathway for tailings drainage, especially where paleochannels exist and cut into the Mancos Shale bedrock as noted in this section. Up to 25 ft of weathered alluvial material mantles Mancos Shale at the site. Horizontal hydraulic conductivity and vertical hydraulic conductivity have been determined for the weathered Mancos Shale, but hydraulic conductivity has not been determined for the alluvial material overlying the weathered Mancos. If hydraulic conductivity is greater within the unconsolidated overlying material, which is likely the case, this may allow for preferred pathway or a "path of least resistance" for tailings drainage to seep from the tailing pile along this contact and migrate downgradient and offsite.

Response:
Excavation for construction of the disposal cell will be through Quaternary alluvial/colluvial soils and into the weathered Mancos Shale. In addition, the inside slope

of the disposal cell excavation will be tied into the compacted perimeter embankment. Where buried swales exist that are deeper than the average depth of excavation, the unconsolidated materials will be excavated from the buried swales. Therefore, potential pathways for lateral tailings drainage migration will be cut off by the inside slope of the disposal cell excavation and the compacted perimeter embankment. Tailings drainage will thus progress vertically downward into the weathered Mancos Shale. The DOE response to comment GT10 describes what happens to the tailings drainage after it enters the weathered Mancos Shale.

GW2. Calculate the approximate volume of leachate that may drain from the tailings and the volume of water that is expected to seep through the cover. Estimate the distance and depth this volume of leachate may seep from the tailings impoundment.

RASR, page 4-8, section 4.3.4. The statement is made that "the average moisture content of the tailings will probably be biased on the wet side of optimum, leaving enough residual moisture to drain from the tailings under the influence of gravity." The cover will have a lower hydraulic conductivity than the underlying Mancos Shale to prevent "bathtubbing." Has DOE attempted to calculate the approximate amount of leachate that may drain from the volume of tails expected based on an approximation of "the wet side of optimum?" If so, has the volume of Water calculated been modeled to determine its approximate flow path and distance from the site? There is a concern that leachate may not penetrate the weathered Mancos Shale and prefer to migrate along the weathered Mancos Shale and Quaternary alluvial material contact. If this were to occur, would this result in offsite drainage or the possible development of seeps in either Crescent or Kendall Washes, especially if leachate were to migrate along the paleochannel(s) cited in the text?

The text in this section also notes that DOE will monitor the accumulation of transient drainage with a standpipe tapping a sump at the downgradient toe of the disposal cell. How far into the weathered Mancos Shale is the sump to be constructed or will it only be in the alluvial material? Is only one sump anticipated, or will a series of sumps be considered at the downgradient toe of the cell? Please clarify or develop a plan and basis for location of the sumps. Clarify the "action level" and the plan for pumping and disposal of water from the sump(s).

Response:
The water content of the Moab tailings as excavated and hauled to the Crescent Junction Disposal Cell is likely to be near optimum to above optimum relative to the required compaction effort (at Standard Proctor density). The tailings are anticipated to lose moisture, becoming nearly optimum in water content because of evaporation that is anticipated to occur during mixing, dumping and spreading of the tailings prior to compaction.

The excavated Moab tailings will be placed in the disposal cell and processed by the following procedure: (1) dumping from trucks along a working face or specific area, (2) spreading in lifts with a dozer, and (3) compacting each lift of tailings with a compactor. This tailings-handling process, when performed in an arid climate such as that at the

Crescent Junction Site, should dehydrate the tailings to nearly optimum water content during compaction in the cell. Evaporation from the compacted tailings surface should continue to dry the tailings further until the subsequent lift of tailings is placed. Water will be added as necessary (by spraying) for dust suppression.

Based on experience at other DOE Title I sites where uranium mill tailings have been relocated, some drainage of tailings porewater has been observed. Sumps will be constructed in weathered Mancos Shale, along the downslope (south) side of the cell, as a best management practice to collect potential drainage from the tailings. The volume of leachate that might drain from the tailings can be estimated from the difference between the water content of the tailings at optimum water content and at residual water content (drained conditions). This estimate is inherently biased to the high side because evaporation of porewater from the surface of the tailings is expected during dumping, spreading, and compaction, and during the intervening time between placement of successive lifts of tailings.

The average water content (by dry weight) of the transitional tailings at optimum conditions for compaction is approximately 18 percent, and the residual water content averages approximately 15 percent. For 12 million yd^3 of compacted RRM (primarily tailings), this water content difference is equivalent to approximately 5 percent of the total RRM volume, or 600,000 yd^3 (121 million gallons) of leachate. This volume draining over the anticipated period of RRM placement (approximately 20 years) results in an average drainage rate of 12 gpm.

Leachate from the disposal cell would migrate downward as unsaturated flow through the weathered Mancos Shale until it reaches the unweathered Mancos Shale, approximately 60 to 80 ft beneath the original ground surface. Because the conservatively estimated seepage flux (approximately 0.15 ft/year averaged over the footprint of the disposal cell) is higher than the hydraulic conductivity of the unweathered Mancos Shale (approximately 0.036 ft/year as the geometric mean from packer testing), the leachate could perch at the top of the unweathered Mancos Shale and would be expected to migrate laterally along the top of the unweathered Mancos Shale. During the performance life of the disposal cell, conservatively estimated accumulation of leachate and its lateral migration would occur entirely within the weathered Mancos Shale. If more reasonable assumptions are considered, there would be no accumulation or lateral spreading of leachate below the disposal cell (RAP Attachment 3, Appendix G).

GW3. Provide additional data, evidence, or research to support the claim that water in the Mancos Shale beneath the cell location is connate water.

Attachment 3, Appendix D, page 4. The statement is made that "Coreholes 0201, 0203, 0204, and 0208 have continued to yield water at relatively constant rates, signifying that the connate water intercepted by these coreholes is stored in larger compartments, which will require more pumping to deplete. The continued pumping from these larger compartments is deemed unnecessary because the concept that the connate water is trapped in porous zones with limited volume was already demonstrated at corehole 0202."Provide a basis that water in four coreholes is stored in larger compartments. Has DOE considered that fractures may have provided a connection for groundwater flow, thus indicating that behavior of water in the four coreholes is more indicative of groundwater flow than that of corehole 0202?

Response:
The ground water in the Mancos Shale is suspected to be connate based on several factors, including its salinity, variable ground water levels, and isolation from sources of recharge. In August 2006, the ground water was sampled in wells 0203 and 0208 and analyzed for radiocarbon (^{14}C). Results of the analyses show that the age of the ground water exceeds 40,000 years, which is the approximate detection limit for radiocarbon age dating; this would make the ground water at least late Pleistocene in age. A complete summary of the sampling and analysis of the ground water is presented in a new calculation set for Radiocarbon Age Determinations for Ground Water Samples Obtained from Wells 0203 and 0208 (RAP Attachment 3, Appendix F).

GW4. Attachment 4, Appendix B, page 35, section 8.7.2. Discuss proposed modifications to the model based on the likelihood that much of the groundwater transport through the Mancos Shale is through fractures or other large-scale features.

On the very last line of section 8.7.2, the comment is made that, "Thus, if ground water moves dominantly by fracture flow, some modifications will likely be required." In section 8.8, paragraph two, the statement is made, "Because of the low-bulk hydraulic conductivity, much of the ground water transport through the Mancos Shale is likely to be through fractures or other large-scale features. Based on the two statements, modifications of the model may be required." Discuss what modifications have been made to the model to resolve this discrepancy.

Response:
The following text section from Section 8.8 of the calculation describes how the model would be adapted to fracture flow:

> "Adaptation of the model to fracture flow would be accomplished by decreasing the concentrations of sites and minerals (normalizing to a liter of ground water)."

However, no modifications to the model are deemed necessary because the Mancos Shale is preeminently a confining unit that contains isolated pockets of connate, briny ground water, which exists in fractures and apertures and is essentially immobile. The Mancos Shale provides effective hydrogeologic isolation to the Crescent Junction Disposal Site. If through-flow were to exist, it would be under the conditions of very long travel times, as indicated by the ^{14}C age date, exceeding 40,000 BP, which was obtained for the uppermost ground water.

GW5. Attachment 4, Appendix B, page 35, section 9.0, paragraph 2. Discuss what hydrologic investigations are to be used to yield more useful units of travel time and distance for the model, or alternatively, provide a sensitivity analysis to assess the impact of chemical attenuation at the site.

One of the conclusions of Appendix B is that project personnel will need to couple the results from the model with the results from hydrologic investigations to yield more useful units of travel time and distance. Furthermore, in lieu of further investigations, a sensitivity analysis is proposed to assess the impact of chemical attenuation at the site. Provide the additional analysis as based on the conclusion in this Appendix.

Response:
The hydrologic investigations required for improving the travel time and distance estimates were conducted as part of the Hydrologic Characterization. The data interpretation presented in the calculation set for Vertical Travel Time to Uppermost (Dakota) Aquifer (RAP Attachment 3, Appendix E) develops the travel time and distance topics requested in this comment. The resulting travel time ranges from 4,860 to 48,600 years based on effective porosities of 0.05 and 0.005, respectively. These porosities are a factor of 50 and 5, respectively, lower than the porosity of 0.25 that was used in the geochemical calculation. If a porosity of 0.25 is used in the calculation, the resulting travel time to the uppermost (Dakota) aquifer becomes 243,000 years.

Radon Attenuation and Site Cleanup

R1. Please provide more detail on the process for inclusion or exclusion of identified vicinity properties.

Response:
DOE has committed to perform gamma surveys on all of the properties on the EPA list. The surveys will also include soil samples from the areas of highest gamma readings to demonstrate compliance with Radium-226 soil standard. From these measurements an inclusion/exclusion report will be prepared, documenting whether a property exceeds the EPA standards (an inclusion) or does not exceed, resulting in an exclusion.

DOE will follow the enclosed flowchart in making the inclusion/exclusion decision. The flowchart was revised to reflect NRC comments. Instead of relying on visual evidence to confirm the presence of tailings, DOE will rely on visual evidence to confirm that a point source is caused by uranium ore, fossil wood, or fossil dinosaur bones. Point sources usually stand out as gamma anomalies with readings from 100 to 1,000 microroentgens per hour.

Consequently, vicinity properties will be excluded if gamma and soils samples do not exceed EPA standards or if the only elevated readings are point sources caused by uranium ore, fossil wood, or fossil dinosaur bones. An included property will undergo further assessment on both the exterior and interior of the structure to ensure all deposits exceeding EPA standards are identified and remediated.

R2. Please provide more detail on which areas will require supplemental standards and the justification for use of supplemental standards on these areas.

Response:
DOE is currently considering the use of supplemental standards on several areas on the millsite, Policaro vicinity property, and BLM properties surrounding the millsite. Examples of where DOE does not plan to remediate include: contamination under the highway asphalt; contamination around high-pressure natural gas lines and buried electric and fiber optic lines; and contamination on steep slopes where access is not feasible and cleanup would cause excessive environmental damage.

DOE understands that additional information is required to substantiate the application. Depending on which provision of 40 CFR 192.22 is cited, the following minimum information is provided:

Proposed use and justification of applying supplemental standards.

Engineering alternatives studied, including costs to implement.

Radiological levels.

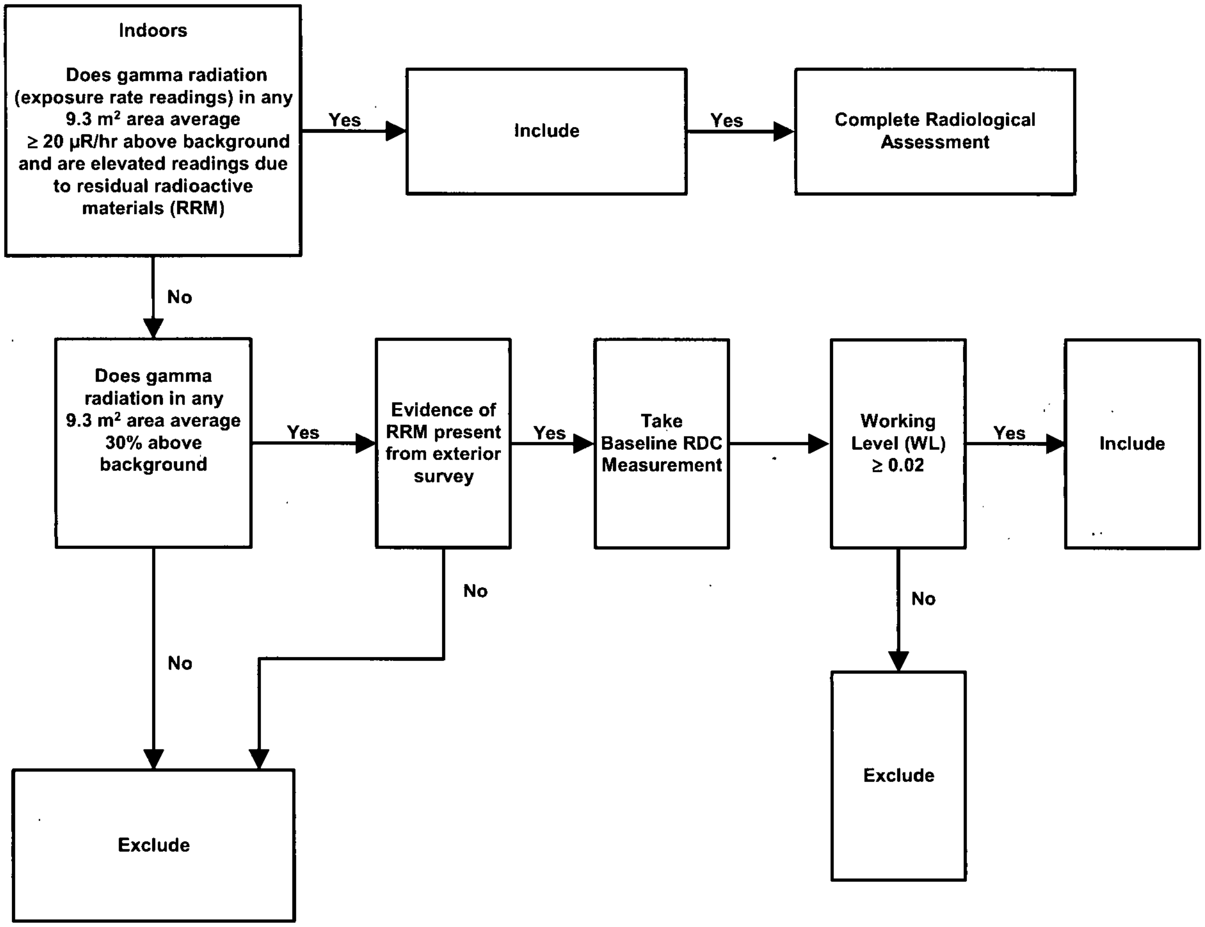
Health risks of leaving RRM behind.

Potential for tailings movement or disturbance.

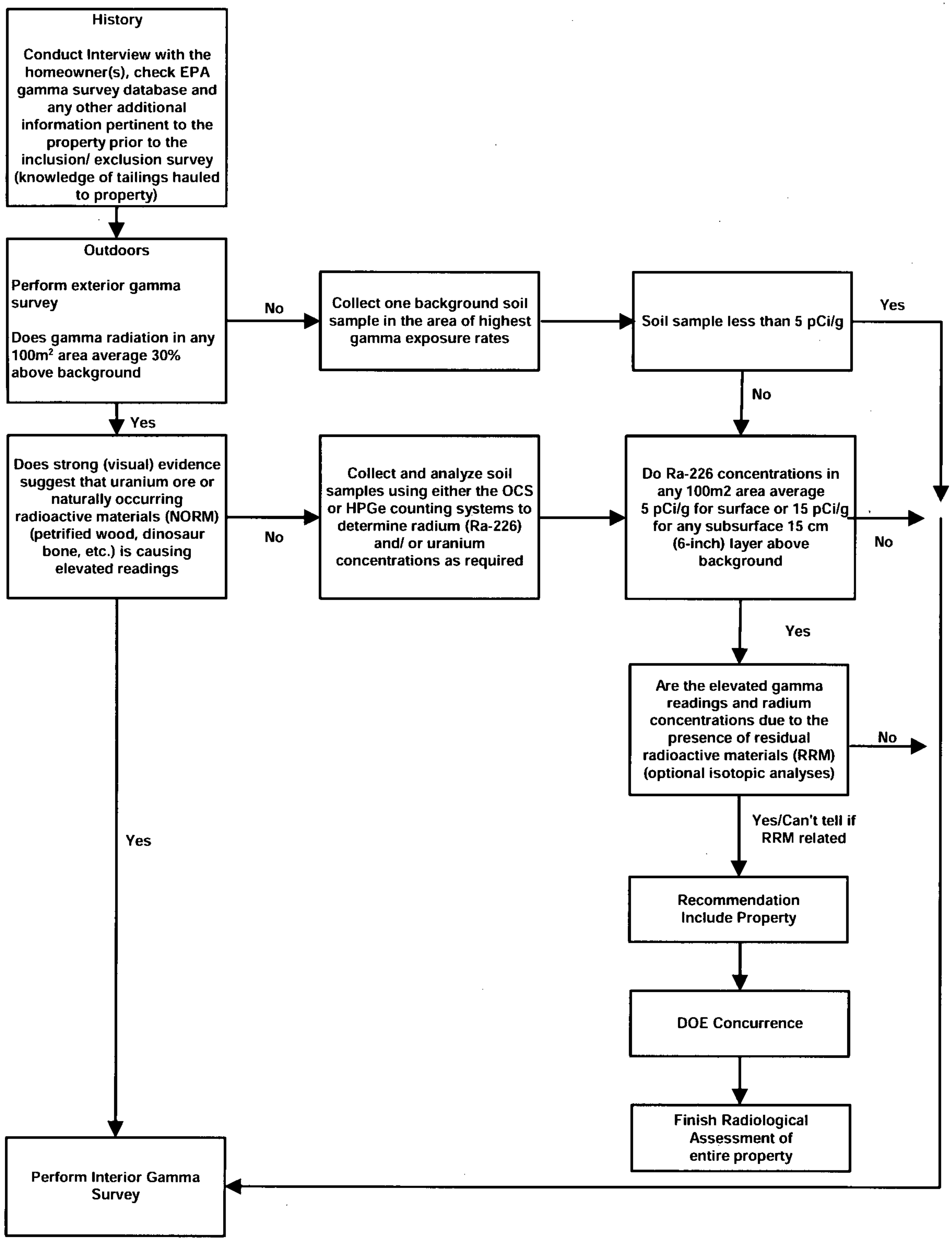
Property owners' notification and input.

DOE has a lot of experience in applying supplemental standards for similar scenarios at other UMTRA sites and can share examples if NRC desires.

Interior Inclusion/Exclusion Survey



Exterior Inclusion/Exclusion Survey



September 2007 Open Issues Meeting

Further response for February 2007 GT (Geotechnical) Issues

1. **GT 2 -** As part of its volume balance analysis, DOE indicates that a 13 to 15 percent shrinkage factor should be applied from excavated material to compacted material. DOE uses the 15 percent shrinkage factor for the UMTRA cover option, but only assumes an 8 percent shrinkage for the Alternative cover. DOE needs to explain the basis for using an 8 percent shrinkage factor for the Alternative cover, or otherwise describe the source of material to make up the shortage if the 15% shrinkage factor also applies to the Alternative cover.

   Response
   The final design uses the UMTRA cover option. The alternative cover has been dropped.

2. **GT 3 -** In response to the previous request for additional information on swelling clays, DOE has indicated that "the weathered Mancos Shale is likely to be slightly to moderately expansive in the area of the disposal cell, which can be accommodated in the design of the disposal cell." In the final RAP, DOE needs to include information on how it has factored or plans to factor the Mancos Shale expansive characteristics into the cell design.

   Response
   The Mancos Shale formation can exhibit characteristics of moderate swelling, due to the possible presence within the shale of expansive clays and thin gypsum lenses, which expand when hydrated. Though possible, expansion of the shale is not considered to be problematic for the following reasons:

   a) The shale formation has extremely low hydraulic conductivity, and though the top surface of the shale will be wetted during the time when tailings are being placed and later as excess capillary water migrates to and along the cell floor the water will not migrate very far into the shale formation. The thickness of the shale being wetted is not likely more than 1 to 2 feet and the volume of expansive clay or gypsum in that thin layer of shale cannot expand enough to be of consequence. For example, if two feet of shale is hydrated, and 25% of the two feet thickness is expansive material, and the expansive material expands 50% (typical for some types of gypsum) the total expansion would be 3 inches.

   b) Minor expansion, if it occurs, will take place when the Mancos shale is initially wetted. At that point, the cell is being excavated and the first layers of tailings are being placed. There will not be anything in place at that point that could be damaged by minor soil movement. Damage from soil expansion and contraction tends to occur when a sensitive structure such as a building or highway undergoes differential movement. The disposal cell is not a sensitive structure, especially in the early stages of cell excavation and tailings placement.

c) Expansion and/or contraction of expansive soils takes place when significant changes in moisture content occur. When moisture content is relatively constant, expansion and/or contraction does not occur. A relatively thin layer of Mancos shale may expand when initially hydrated, but once several feet of tailings have been placed over the shale, the moisture content at the cell floor should remain relatively constant. Whether the cell eventually dries out or has some residual moisture at the cell floor long-term, it should not be subject to moisture fluctuations that would result in significant cycles of expansion and contraction.

Geotechnical Stability

3. At this time, DOE has indicated that construction details will provided with the final RAP. This will include the proposed sequence of construction and the detailed construction specifications, including contaminated material and cover layer placement procedures, Therefore, until this information is submitted and reviewed, the approval of construction details and specifications remains an open issue.

Response
In the final RAP, Section 7.2 contains the Construction Details and Addendum B contains the Final Design Specifications.

4. DOE will implement an inspection and testing program to ensure quality control of the construction of the various components of the cell. This program will be described in the Remedial Action Inspection Plan to be submitted with the Final RAP. Therefore, until this information is submitted and reviewed, the approval of the testing and inspection details of the quality control program remains an open issue.

Response
Addendum E contains the Remedial Action Inspection Plan (RAIP) for NRC's review.

5. The factor-of-safety from the DOE slope stability analysis of the long-term pseudo-static condition is just equal to the required minimum value of 1.0 DOE should provide a discussion of these results in terms of the conservative factors in the seismic input assumptions and the analysis as a whole as justification for the factor of safety not exceeding the minimum allowed.

Response
New Slope Stability calculations were performed with computer program, SLIDE, V 5.0 by Rocscience. The SLIDE program analyzes the slope with multiple methods to determine factor of safety, including Bishop Simplified, Janbu Simplified, Janbu Corrected, Spencer, Morgenstern-Price, and Corps of Engineers Methods. Bishop and Janbu methods employ limit equilibrium analysis method, Spencer and Morgenstern-Price

methods use both force equilibrium and moment equilibrium to determine safety factors. In this analysis, Spencer results yielded the lowest factor of safety.

The analysis was performed for the End of Construction (short-term) and Long-term cases. Stability of the disposal cell perimeter embankment and cover system was also assessed for the design seismic event for both the short term and long term cases. Seismic conditions were analyzed using guidance provided in the Technical Approach Document (TAD) 1989. The TAD requires the use of pseudo-static approach where Peak Horizontal Acceleration (PHA) value of 0.22 g (previously determined) is taken as half of PHA or 0.11 g for End of Construction case, and 2/3rd of PHA or 0.15 for Long-term case.

The analysis results, summarized in the following table, indicate that the Safety Factor of the critical slope exceeds the Safety Factor required by the TAD for all of the cases. The stability results indicate that the proposed disposal cell site, perimeter embankments, and cover system will be stable when constructed of on site materials and with the planned embankment geometry.

Summary of Slope Stability Analysis

Loading Condition	Calculated Factor of Safety	Factor of Safety Required by TAD
End-of-construction:		
Static	1.82	1.3
Pseudostatic (k_h = 0.11g)	1.17	1.0
Long-term:		
Static	2.35	1.5
Pseudostatic (k_h = 0.15g)	1.33	1.0

K_h = pseudostatic coefficient

6. Both cover options include a 6-inch "infiltration and biontrusion" layer. DOE should provide a detailed description of the function and composition of this layer, and how the composition will serve to meet the functional requirements.

Response
The Infiltration and Biointrusion layer has two primary functions: limit infiltration of water and limit intrusion of plant roots and burrowing animals into the Radon Barrier Layer.

a) To limit infiltration of water, the layer provides a pathway for water that infiltrates into the overlying soil layer to be conducted to the perimeter of the cover. The conductivity of the Infiltration layer will be several orders of magnitude higher than the underlying compacted clay layer beneath it, and the preferential flow path for water will be through the Infiltration layer to the cover perimeter. The Infiltration layer also serves as a capillary break, limiting the head pressure that can occur above the Radon Barrier layer.

b) To limit intrusion of roots and burrowing animals, a 4-ft thick soil layer is placed above the Biointrusion layer made up of a sandy gravel with a D_{50} stone size of 2 inches. The combination of a thick soil layer and a large stone has been shown to be an effective deterrent to further penetration of both roots and animals.

7. In its alternate monolithic cover design, DOE merely indicates a thick mixture of alluvial, Aeolian, and Mancos shale materials. Unless this cover option is eliminated in the final design, DOE should provide a discussion of how it would be constructed to provide a cover of less than or equal to 10-7 cm/sec infiltration rate.

   Response
   The alternative cover option has been eliminated.

Surface Water Hydrology and Erosion Protection

8. Design of Riprap for the Diversion Channel Outlet: Staff review of the design of the riprap for the diversion channel outlet indicates that the rock size and volume may not be adequate to prevent headcutting and gully intrusion into the channel. Based on observations during site visits in the area, it appears that existing gullies along the west and southwest sides of the disposal cell are deeper than the proposed scour depth of 5 feet. The staff has observed several gullies that are significantly deeper than 5 feet, and the increased drainage area from the north diversion channel may result in gullies that will be similar in depth.

   Although the scour model used may be acceptable, the assumptions related to flow distribution across the outlet structure do not appear to adequately account for localized flow concentrations.

   The design condition for computing the scour depth, rock size, and volume should be based on assumed areas of very large flow concentrations occurring downstream of the outlet structure. The current assumption of a flow concentration of 3 is probably not adequate. In addition, DOE should carefully analyze the gullies that currently exist and determine an appropriate scour depth for the design of the diversion channel outlet, based on potential headcutting of existing gullies. This information was originally requested in geomorphic comments that were submitted earlier (Comment 3c from 04/06 meeting).

   Response
   The revised cell design has replaced the north diversion channel with a wedge of compacted surplus material from the excavation. Flow from the north will be diverted around the disposal cell to the east and west. An analysis of sediment transport potential and sediment supply to the area immediately north of the wedge indicates that the wedge will not erode but rather trap sediment from the north and increase in volume over time. After the flow turns southerly at the ends of the wedge it will erode channels that will carry the flow to the east and west branches of Kendall Wash after bypassing the disposal cell.

Although the natural ground slope will not direct the flow toward the disposal cell, large diversion berms are to be constructed to ensure that the flow will bypass the cell.

9. Selection of Rock Source: The staff notes that DOE has considered several rock sources, but has not selected any specific source. The staff also recognizes that DOE does not plan to produce and place rocks until several years in the future. However, the staff considers it important for DOE to preliminarily select a specific source and use data from that source to develop a complete design and construction package. Even though DOE has committed to using design criteria such as NUREG-1623 and other NRC suggested guidance, this should be done in the interest of resolving as many issues as possible, prior to construction.

   It is important to note that the sizing and the design of the erosion protection is dependent on the specific gravity of the rock, the angularity of the rock, and the quality of the rock placement. For example, the specific gravity is currently assumed to be 2.65, but this may be optimistic for a sandstone source. The rock is also assumed to be angular, but if rounded boulders are used, the rock size may need to be increased by as much as 40 percent.

   The staff considers that DOE should develop a preliminary design that is based on the use of a specific rock source. DOE should then provide data from this source regarding rock durability tests, rock production procedures (at the proposed quarry), rock placement procedures, and other QA/QC information.

   Response
   A source for the riprap will be selected and included as a part of the final RAP along with rock durability tests, rock production (at the proposed quarry), and rock placement.

   The Aggregate and Riprap specification contains the following quality requirements:

NRC TABLE OF SCORING CRITERIA FOR ROCK QUALITY

Laboratory Test	**Weighing Factor**			**Score**										
	Limestone	**Sandstone**	**Igneous**	10	9	8	7	6	5	4	3	2	1	0
Specific Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.30	2.25
Absorption, %	13	5	2	0.10	0.30	0.50	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
LA Abrasion, % (100 revolutions)	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmitt Hammer	11	13	3	70	65	60	54	47	40	32	24	16	8	0

Notes:

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642, *Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, 1982.*

2. Weighing Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G.W. Dupuy, *Engineering Geology*, July 1965. Weighing factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighing factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR2642, so that proper correlations can be made.

ACCEPTABLE ROCK SCORES

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 pile, the rock must score at least 50% or the rock is rejected. If the rock scores between 50% and 80% the rock may be used, but a larger D_{50} must be provided (oversizing). If the rock score is 80% or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65% or the rock is rejected. If the rock scores between 65% and 80%, the rock may be used, but must be oversized. If the rock score is 80% or greater, no oversizing is required.

ROCK OVERSIZING

Oversize rock as follows;

- Subtract the rock score from 80% to determine the amount of oversizing required. For example, a rock with a rating of 70% will require oversizing of 10 percent (80% - 70% = 10%).
- The D_{50} of the stone shall be increased by the oversizing percent. For example, a stone with a 10% oversizing factor and a D_{50} of 12 inches will increase to a D_{50} of 13.2 inches.
- The final thickness of any layer of oversized stone shall increase proportionately to the increased D_{50} rock size. For example, a layer thickness equals twice the D_{50}, such as when the plans call for 24 inches of stone with a D_{50} of 12 inches, if the stone D_{50} increases to 13.2, the thickness of the layer of stone with a D_{50} of 13.2 should be increased to 26.4 inches.

Water resources Protection

10. Points of Compliance: No points of compliance have been established and I don't believe they need to be for chemical concentrations, however, I believe DOE needs to better explain how they will demonstrate cell performance and monitoring for performance. DOE has modeled the expected lateral spreading of contaminants in the weathered Mancos Shale and estimated a 10 year ring, 200 year ring, and 1000 year ring. I would think that if contamination is expected t spread to the 10 year ring, why not monitor for cell performance? If no contamination or fluids occurs at year 10, cell is performing better than anticipated. If it occurs before, DOE should have a plan to install wells at further out to monitor for performance. No chemically, only the presence or absence of cell fluid is needed to monitor performance because the geochemical nature of the Mancos (saline and briny) and its been written off as a source of water. AI also believe that DOE should be specific as to how many standpipes are going to be installed to monitor cell performance, at the edge of the cell. In RAP, Attachment 3, Appendix G, page 12, last bullet, states, "Up to three piezometers (standpipes) are recommended to monitor the accumulation of leachate within the footprint of the disposal cell, during the transient drainage period, to verify that bathtubbing dissipates as steady-state conditions are achieved. In addition, the piezometer may be used to monitor subsurface hydrologic condition after steady-state drainage is achieved." However, the RAP, page 4-7 states, "DOE will monitor the accumulation of transient drainage with a standpipe tapping a sump at the down gradient toe of the disposal cell...." And on top of page 9-2, "A temporary standpipe to monitor transient drainage is discussed in Section 4.0 of this document." I take this statement to mean DOE has discarded the recommendation made in the RAP, Attachment 3, Appendix G, page 12.

Basically, I have two concerns.

1. DOE should monitor the toe of the cell for leachate and cell performance to make sure they do not have fluids migrating at the unweathered Mancos Shale - Alluvial material interface. I think one locations is not enough for a cell of this size and is contrary tot eh recommendation in the RAP. These multiple locations should be defined.
2. The overall performance of the cell and the disposal strategy of allowing the cell to leak over time needs to be confirmed. DOE has determined that all the fluids will be contained within a defined perimeter around the cell and within the weathered Mancos Shale. They should be require to monitor for this performance for the presence/absence of cell fluids.

Response

The disposal cell has been designed with four locations for standpipes to monitor the presence/absence of cell fluids. The 4 standpipes are along the down gradient interior boundary of the cell (Addendum C Final Design Drawings) The details of the standpipe are shown on drawing E-02-C-104 in that Addendum. If any water accumulates in the standpipe following closure of the cell it can be removed and stored in a cell water retention pond.

During construction of the cell, the slope of the bottom will promote drainage to a temporary sump in the dirty construction area. This water will either evaporate or will be pumped and used as dust control on contaminated areas within the cell. As the construction continues, the amount of water accumulation at the fresh face of construction can be monitored along with any water in the already installed standpipes. This would also provide information for documentation and for future planning.

A decision on future action to monitor water outside the cell would be developed under an observational approach. If there were indications that a larger volume of water than anticipated was accumulating within the cell, there would be studies/modeling performed to ascertain what or if there was an impact and if further action was warranted.

Radon Attenuation and Site Clean Up

11. Editorial: 9.1.3 DOE states that for Th-230 a supplemental standard under criterion "f" will be imposed. 192.21 f refers to the restoration of groundwater. Did they mean "h"?

Response
The correction will be included.

12. Analytical: 9.1.3 DOE stated they will use statistical correlations for radium in lieu of soil sampling. They also state that thorium may be an issue on site. If an area contains RRM other than Ra-226 wouldn't that cause correlations to be severely inaccurate?

Response
The correlation is based on gamma or exposure rate readings detected in the field. If an area contains RRM other than Ra-226, such as Th-230, it would not affect the radium in soil versus gamma correlation due to the fact that Th-230 does not contribute significant amounts of gamma radiation. For the areas identified on the site that may contain RRM other than Ra-226, the soil sampling frequency will be increased in order to adequately demonstrate that the appropriate soil clean-up standards have been met.

ADDENDUM B

Final Remedial Action Plan
DOE-EM/GJ1547
February 2008

Final Design Specifications

FOR EASY NAVIGATION – CLICK ON SECTION NAME / LINK ABOVE

OR USE BOOKMARKS TAB AT LEFT

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MOAB UMTRA PROJECT **MOAB, UTAH** **PROJECT NO: 35DJ2600**	DOCUMENT NO.: 35DJ2600-056-SPEC-31-00-00 SECTION NO.: 31-00-00 EARTHWORK

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	1/30/08	WDB	FMP	W. Barton	ALL	Page 16: Added Section 3.11.1.2 Pages 18-19, revised soil testing frequencies
2	2/27/08	WDB WDB	FMP	W. Barton WDB	ALL	Revised per DOE & Golder Comments Page 6 Section 1.2.7: revised to reference Section 32 11 23, AGGREGATE AND RIPRAP Page 7, Section 1.5: revised to include topsoil. Page 10, Section 3.1.5: revised to include additional requirements for safe trench excavation. Page 12, Section 3.4: revised to add sediment/erosion control to stockpile areas. Page 13, Section 3.6.2: revised to delete word muddy. Page 14, Section 3.9.1.3: revised to include sand (SW). Page 19, Section 3.14.2: revised frequency of check tests.

REGISTERED PROFESSIONAL ENGINEER
No. 6785479-2202
FRANKLIN M. PARTON JR.

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DIVISION 31 - EARTHWORK

SECTION 31 00 00

EARTHWORK

-- End of Section Table of Contents --

SECTION 31 00 00

EARTHWORK

PART 1 GENERAL

This Earthwork Specification covers most of the earthwork in support of the Moab UMTRA Project, including work at the Moab site, at Crescent Junction, and for the Green River to Crescent Junction Water Line. Earthwork not covered by this specification (covered under separate specifications) includes the Haul Road work at Moab, Placement and Compaction of Tailings and Interim Cover, and Placement and Compaction of Final Cap Layers.

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO T 99	(2001; R 2004) Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in) Drop
AASHTO T 180	(2001; R 2004) Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in) Drop
AASHTO T 224	(2001; R 2004) Correction for Coarse Particles in the Soil Compaction Test

ASTM INTERNATIONAL (ASTM)

ASTM A 139	(2004) Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)
ASTM C 136	(2006) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 33	(2003) Standard Specification for Concrete Aggregates
ASTM D 698	(2000ae1) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu ft)
ASTM D 1140	(2000) Amount of Material in Soils Finer than the No. 200 (75-micrometer) Sieve
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 1557	(2002e1) Standard Test Methods for

	Laboratory Compaction Characteristics of Soil Using Standard Effort (56,000 ft-lbf/cu ft)
ASTM D 1883	(2005) CBR (California Bearing Ratio) of Laboratory-Compacted Soils
ASTM D 2487	(2006) Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 422	(1963; R 2002e1) Particle-Size Analysis of Soils
ASTM D 4318	(2005) Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 6938	(2007b) In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D 2216	(2005) Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
ASTM D 4944	(2004) Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by Direct Heating

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1	(2004) Structural Welding Code - Steel

1.2 DEFINITIONS

1.2.1 Satisfactory Materials

Satisfactory materials comprise any materials classified by ASTM D 2487 as GW, GP, GM, GP-GM, GW-GM, GC, GP-GC, GM-GC, SW, SP, SM, SW-SM, SC, SW-SC, CL, ML, and CL-ML. Satisfactory materials for grading comprise stones less than 4 inches, except for fill material for pavements and railroads which comprise stones less than 3 inches in any dimension.

1.2.2 Unsatisfactory Materials

Materials which do not comply with the requirements for satisfactory materials are unsatisfactory. Unsatisfactory materials include man-made fills; trash; refuse; backfills from previous construction; and material classified as satisfactory which contains root and other organic matter or frozen material. Notify the Construction Manager when encountering any contaminated materials.

1.2.3 Degree of Compaction

Degree of compaction required, except as noted in the second sentence, is expressed as a percentage of the maximum density obtained by the test procedure presented in ASTM D 698 or ASTM D 1557 abbreviated as a percent of laboratory maximum density. Since ASTM D 698 and ASTM D 1557 apply only to soils that have 30 percent or less by weight of their particles retained on the 3/4 inch sieve, express the degree of compaction for material having more than 30 percent by weight of their particles retained on the 3/4 inch sieve as a percentage of the maximum density in accordance with AASHTO T 99 or AASHTO T 180 and corrected with AASHTO T 224.

1.2.4 Rock

Solid homogeneous material with firmly cemented, laminated, or foliated masses or conglomerate deposits, neither of which can be removed without systematic drilling and blasting, drilling and the use of expansion jacks or feather wedges, or the use of backhoe-mounted pneumatic hole punchers or rock breakers; also large boulders, buried masonry, or concrete other than pavement exceeding 1/2 cubic yard in volume.

1.2.5 Unstable Material

Unstable materials are too soft or unstable to properly support the utility pipe, conduit, or structure.

1.2.6 Select Granular Material

1.2.6.1 General Requirements

Select granular material consists of materials classified as GW, GP, SW, or SP, or by ASTM D 2487 where indicated. Not more than 30 percent by weight may be finer than No. 200 sieve when tested in accordance with ASTM D 1140.

1.2.6.2 California Bearing Ratio

California Bearing Ratio (CBR) tests are intended to evaluate the strength of pavement subgrade. Perform CBR tests on select granular material in accordance with ASTM D 1883 for a laboratory soaking period of not less than 4 days. Prepare and compact specimens at 95 percent ASTM D 1557 maximum density.

1.2.7 Pipe Bedding Material

Pipe bedding material shall consist of select granular material in accordance with Section 32 11 23, AGGREGATE AND RIPRAP.

1.2.8 Expansive Soils

Expansive soils are defined as soils that have a soil Activity number greater than 1.25, where Activity(Ac) = Plasticity Index / percent finer than .002mm.

1.2.9 Nonfrost Susceptible (NFS) Material

Nonfrost susceptible material is a uniformly graded gravel or washed sand with no more than 3 percent smaller than .002mm.

1.3 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Shoring; G;

Blasting; G;

Submit 15 days prior to starting work.

SD-03 Product Data

Utilization of Excavated Materials;

Rock Excavation

Opening of any Excavation or Borrow Pit

Procedure and location for disposal of unused satisfactory material. Proposed source of borrow material. Notification of encountering unrippable rock in the project. Advance notice on the opening of excavation or borrow areas.

SD-06 Test Reports

Borrow/Fill Material Testing

Compaction Testing

Within 24 hours of conclusion of physical tests, 3 copies of test results, including calibration curves and results of calibration tests.

SD-07 Certificates

Testing

Qualifications of the testing laboratory.

1.4 SUBSURFACE DATA

Subsurface soil boring logs are available for elements of this project. These data represent the best subsurface information available; however, variations may exist in the subsurface between boring locations.

1.5 CLASSIFICATION OF EXCAVATION

Excavation will be designated as topsoil, common excavation, Mancos Shale, or rock excavation.

1.5.1 Topsoil

Topsoil is defined as the top one ft of natural soil at Crescent Junction.

1.5.2 Common Excavation

Common excavation includes all materials not classified as Mancos shale or rock excavation.

1.5.3 Rock Excavation

Include rock excavation with blasting, excavating, grading, disposing of material classified as rock, and the satisfactory removal and disposal of boulders 1/2 cubic yard or more in volume; solid rock; rock material that is in ledges, bedded deposits, and unstratified masses, which cannot be removed without systematic drilling and blasting; firmly cemented conglomerate deposits possessing the characteristics of solid rock impossible to remove without systematic drilling and blasting; and hard materials (see Definitions). Include the removal of any concrete or masonry structures, except pavements, exceeding 1/2 cubic yard in volume that may be encountered in the work in this classification. If at any time during excavation, including excavation from borrow areas, the Contractor encounters material that may be classified as rock excavation, uncover such material and notify the Construction Manager. The Contractor shall not proceed with the excavation of this material until the Construction Manager has classified the materials as common excavation or rock excavation and has taken cross sections as required. Failure on the part of the Contractor to uncover such material, notify the Construction Manager, and allow ample time for classification and cross sectioning of the undisturbed surface of such material will cause the forfeiture of the Contractor's right of claim to any classification or volume of material to be paid for other than that allowed by the Construction Manager for the areas of work in which such deposits occur.

1.5.4 BLASTING

Blasting shall be limited to that required for a quarrying operation to provide rock for the Waste Cell construction at Crescent Junction. At other project locations, blasting to break rock for excavating shall be performed only if no other method of rock removal will work, and only with prior written approval of a blasting plan. The Contractor shall submit a Blasting Plan in conformance with Federal, State, and local safety regulations, prepared and sealed by a registered professional engineer that includes calculations for overpressure and debris hazard. Provide blasting mats and use the non-electric blasting caps. Obtain written approval prior to performing any blasting and notify the Construction Manager 24 hours prior to blasting. Include provisions for storing, handling and transporting explosives as well as for the blasting operations in the plan. The Contractor is responsible for damage caused by blasting operations.

1.6 DEWATERING

Perform dewatering of work areas in accordance with the project plans and specification section 31 32 11, SURFACE-WATER MANAGEMENT AND EROSION CONTROL.

PART 2 PRODUCTS

2.1 BURIED WARNING AND IDENTIFICATION TAPE

Provide polyethylene plastic warning tape manufactured specifically for warning and identification of buried utility lines. Provide tape on rolls, 3 inch minimum width, color coded as specified below for the intended utility with warning and identification imprinted in bold black letters continuously over the entire tape length. Warning and identification to read, "CAUTION, BURIED (intended service) LINE BELOW" or similar wording. Provide permanent color and printing, unaffected by moisture or soil.

Warning Tape Color Codes

[Red:]	[Electric]
[Orange:]	[Telephone and Other Communications]
[Blue:]	[Water Systems]
[Green:]	[Sewer Systems]

2.2 MATERIAL FOR RIP-RAP

Provide filter fabric between soil and riprap in accrdance with 31 05 19 GEOTEXTILE and rock conforming to RIPRAP in accordance with 32 11 23 AGGREGATE AND RIPRAP.

2.3 PIPE BEDDING MATERIAL

Provide bedding material consisting of sand, gravel, or crushed rock, open graded with a maximum particle size of 3/8 inch. Compose material of tough, durable particles. Bedding material shall be free of fines passing the No. 200 standard sieve.

2.4 CAPILLARY WATER BARRIER

Provide capillary water barrier of clean, open graded crushed rock, crushed gravel, or uncrushed gravel placed beneath a slab with or without a vapor barrier to cut off the capillary flow of pore water to the area immediately below. Conform to ASTM C 33 for fine aggregate grading with a maximum of 3 percent by weight passing ASTM D 1140, No. 200 sieve.

2.5 PIPE CASING

2.5.1 Casing Pipe

ASTM A 139, Grade B. Match casing size to the outside diameter and wall thickness as indicated on the drawings. Protective coating is not required on casing pipe.

PART 3 EXECUTION

3.1 GENERAL EXCAVATION

Perform excavation of every type of material encountered within the limits of the project to the lines, grades, and elevations indicated on the drawings. Excavate unsatisfactory materials encountered within the limits of the work below grade and replace with satisfactory materials as directed. Dispose of unsatisfactory excavated material in designated waste or spoil areas. During construction, perform excavation and fill in a manner and sequence that will provide proper drainage at all times. Excavate material required for fill or embankment in excess of that produced by excavation within the grading limits from the borrow areas indicated or from other approved areas selected by the Contractor.

3.1.1 Ditches, Gutters, and Channel Changes

Finish excavation of ditches, gutters, and channel changes by cutting accurately to the cross sections, grades, and elevations shown on the drawings. Do not excavate ditches and gutters below grades shown. Backfill the excessive open ditch or gutter excavation with satisfactory, thoroughly compacted, material or with suitable stone or riprap to grades shown. Dispose of excavated material as shown or as directed, except in no case allow material be deposited a maximum 4 feet from edge of a ditch. Maintain excavations free from detrimental quantities of brush, sticks, trash, and other debris until final acceptance of the work.

3.1.2 Drainage Structures

Make excavations to the lines, grades, and elevations shown, or as directed. Provide trenches and foundation pits of sufficient size to permit the placement and removal of forms for the full length and width of structure footings and foundations as shown. Clean rock or other hard foundation material of loose debris and cut to a firm, level, stepped, or serrated surface. Remove loose disintegrated rock and thin strata. Do not disturb the bottom of the excavation when concrete or masonry is to be placed in an excavated area. Do not excavate to the final grade level until just before the concrete or masonry is to be placed. Where pile foundations are to be used, stop the excavation of each pit at an elevation 1 foot above the base of the footing, as specified, before piles are driven. After the pile driving has been completed, remove loose and displaced material and complete excavation, leaving a smooth, solid, undisturbed surface to receive the concrete or masonry.

3.1.3 Drainage

Provide for the collection and disposal of surface and subsurface water encountered during construction. Completely drain construction site during periods of construction to keep soil materials sufficiently dry. Construct storm drainage features (ponds/basins) at the earliest stages of site development, and throughout construction grade the construction area to provide positive surface water runoff away from the construction activity and provide temporary ditches, swales, and other drainage features and equipment as required to maintain dry soils. It is the responsibility of the Contractor to assess the soil and ground water conditions presented by the plans and specifications and to employ necessary measures to permit construction to proceed.

3.1.4 Dewatering

While the excavation is open, dewater the construction area to limit accumulation of water in the work area and to prevent damage to finished work. Operate dewatering system continuously until construction work below existing water levels is complete.

3.1.5 Trench Excavation Requirements

Excavate trenches as recommended by the manufacturer of the pipe to be installed. Provide vertical trench walls where no manufacturer's printed installation manual is available. Shore trench walls more than 4.5 feet high, cut back to a stable slope (as defined by OSHA 29 CFR 1926), or provide with equivalent means of protection for employees who may be exposed to moving ground or cave in. Excavate trench walls which are cut back to at least the angle of repose of the soil as determined by a professional geotechnical engineer. "Safe trench excavation is at all times the responsibility of the Contractor."

3.1.5.1 Bottom Preparation

Grade the bottoms of trenches accurately to provide uniform bearing and support for the bottom quadrant of each section of the pipe. Excavate bell holes to the necessary size at each joint or coupling to eliminate point bearing. Remove stones of 1 inch or greater in any dimension, or as recommended by the pipe manufacturer, whichever is smaller, to avoid point bearing.

3.1.5.2 Removal of Unyielding Material

Where unyielding material is encountered in the bottom of the trench, remove such material 6 inches below the required grade and replace with suitable materials as provided in paragraph BACKFILLING AND COMPACTION.

3.1.5.3 Removal of Unstable Material

Where unstable material is encountered in the bottom of the trench, remove such material to the depth directed and replace it to the proper grade with select granular material as provided in paragraph BACKFILLING AND COMPACTION.

3.1.5.4 Excavation for Appurtenances

Provide excavation for manholes, catch-basins, inlets, or similar structures sufficient to leave at least 12 inch clear between the outer structure surfaces and the face of the excavation. When concrete or masonry is to be placed in an excavated area, take special care not to disturb the bottom of the excavation. Do not excavate to the final grade level until just before the concrete or masonry is to be placed.

3.1.5.5 Jacking, Boring, and Tunneling

Unless otherwise indicated, provide excavation by open cut except that sections of a trench may be jacked, bored, or tunneled if, in the opinion of the Construction Manager, the pipe, cable, or duct can be safely and properly installed and backfill can be properly compacted in such sections.

3.1.6 Underground Utilities

For work immediately adjacent to or for excavations exposing a utility or other buried obstruction, excavate by hand. Start hand excavation on each side of the indicated obstruction and continue until the obstruction is uncovered or until clearance for the new grade is assured. Support uncovered lines until approval for backfill is granted by the Construction Manager. Report damage to utility lines or subsurface construction immediately to the Construction Manager.

3.1.7 Structural Excavation

Ensure that footing subgrades have been inspected and approved by the Construction Manager prior to concrete placement.

3.2 SELECTION OF BORROW MATERIAL

Select borrow material to meet the requirements and conditions of the particular fill or embankment for which it is to be used. Obtain borrow material from the borrow areas within the limits of the project site, selected by the Contractor or from approved private sources. The

Contractor is responsible for obtaining and delivering borrow material to the project site.

3.3 SHORING

3.3.1 General Requirements

Submit a Shoring and Sheeting plan for approval 15 days prior to starting work. Submit drawings and calculations, certified by a registered professional engineer, describing the methods for shoring and sheeting of excavations. Finish shoring, including sheet piling, and install as necessary to protect workmen, banks, adjacent paving, structures, and utilities. Remove shoring, bracing, and sheeting as excavations are backfilled, in a manner to prevent caving.

3.3.2 Geotechnical Engineer

The Contractor is required to hire a Professional Geotechnical Engineer to design shoring, and provide inspection of excavations and soil/groundwater conditions throughout construction. The Geotechnical Engineer is responsible for performing pre-construction and periodic site visits throughout construction to assess site conditions. The Geotechnical Engineer is responsible for updating the excavation, sheeting and dewatering plans as construction progresses to reflect changing conditions and submit an updated plan if necessary. Submit a monthly written report, informing the Contractor and Construction Manager of the status of the plan and an accounting of the Contractor's adherence to the plan addressing any present or potential problems. The Construction Manager is responsible for arranging meetings with the Geotechnical Engineer at any time throughout the contract duration.

3.4 STOCKPILE AREAS

Keep stockpiles in a neat and well drained condition, giving due consideration to drainage and erosion controlat all times. Separately stockpile excavated satisfactory and unsatisfactory materials. Protect stockpiles of satisfactory materials from contamination which may destroy the quality and fitness of the stockpiled material.

3.5 FINAL GRADE OF SURFACES TO SUPPORT CONCRETE

Do not excavate to final grade until just before concrete is to be placed. Only use excavation methods that will leave the foundation rock in a solid and unshattered condition. Roughen the level surfaces, and cut the sloped surfaces, as indicated, into rough steps or benches to provide a satisfactory bond. Protect shales from slaking and all surfaces from erosion resulting from ponding or water flow.

3.6 GROUND SURFACE PREPARATION

3.6.1 General Requirements

Remove and replace unsatisfactory material with satisfactory materials, as directed by the Construction Manager, in surfaces to receive fill or in excavated areas. Scarify the surface to a depth of 2 inches before the fill is started. Plow, step, bench, or break up sloped surfaces steeper than 1 vertical to 4 horizontal so that the fill material will bond with the existing material. When subgrades are less than the specified density, break up the ground surface to a minimum depth of 6 inches, pulverizing, and compacting to the specified density. When the subgrade is part fill and part excavation or natural ground, scarify the excavated or natural ground portion to a depth of 12 inches and compact it as specified for the adjacent fill.

3.6.2 Frozen Material

Do not place material on surfaces that are frozen, or contain frost.

3.7 UTILIZATION OF EXCAVATED MATERIALS

Dispose of unsatisfactory excavated materials in designated waste disposal or spoil areas. Use satisfactory material from excavations, insofar as practicable, in the construction of fills, embankments, subgrades, and for similar purposes. Do not waste any satisfactory excavated material without specific written authorization. Dispose of satisfactory material, authorized to be wasted, in designated areas approved for surplus material storage or designated waste areas as directed.

3.7.1 Use of Excavated Material as Fill

Excavated material to be used as fill shall be stockpiled or hauled directly to the fill site. Prior to installation as fill, the material shall be tested to determine the maximum dry density (ASTM D 698)or (ASTM D 1557) and optimum moisture content (ASTM D 2216) of the material. The mositure content of the soil shall be adjusted to near optimum moisture content for compaction. Moisture shall be added to the material in a manner that results in a consistent moisture content throughout the fill. Quick tests of moisture content (ASTM D 4643, ASTM D 4944, or ASTM D 4959) shall be performed as required to maintain moisture control during fill placement.

3.8 BURIED TAPE AND DETECTION WIRE

3.8.1 Buried Warning and Identification Tape

Provide buried utility lines with utility identification tape. Bury tape 12 inches below finished grade; under pavements and slabs, bury tape 6 inches below top of subgrade.

3.9 BACKFILLING AND COMPACTION

Place backfill adjacent to any and all types of structures, and compact to at least 95 percent laboratory maximum density (ASTM D 698) for cohesive materials or 98 percent laboratory maximum density for cohesionless materials (ASTM D 698), to prevent wedging action or eccentric loading upon or against the structure. Prepare ground surface on which backfill is to be placed as specified in paragraph GROUND SURFACE PREPARATION. Provide compaction requirements for backfill materials in conformance with the applicable portions of paragraphs GROUND SURFACE PREPARATION. Finish compaction by sheepsfoot rollers, pneumatic-tired rollers, steel-wheeled rollers, vibratory compactors, or other approved equipment.

3.9.1 Trench Backfill

Backfill trenches to the grade shown. Do not backfill trenches until all specified tests are performed.

3.9.1.1 Replacement of Unyielding Material

Replace unyielding material removed from the bottom of the trench with select granular material or bedding material.

3.9.1.2 Replacement of Unstable Material

Replace unstable material removed from the bottom of the trench or excavation with select granular material placed in layers not exceeding 6 inch loose thickness.

3.9.1.3 Bedding and Initial Backfill

Provide bedding of the type and thickness shown. Place initial bedding material and compact it with approved tampers to a height of at least one foot above the utility pipe or conduit. Bring up the bedding backfill evenly on both sides of the pipe for the full length of the pipe. Take care to ensure thorough compaction of the fill under the haunches of the pipe. Compact backfill to top of pipe to 95 percent of ASTM D 698 maximum density. Provide plastic piping with bedding to spring line of pipe. Provide bedding materials as follows:

a. Clean, coarsely graded natural gravel, crushed stone or a combination thereof, having a classification of SW, GW or GP in accordance with ASTM D 2487 for bedding. Do not exceed maximum particle size of 3/8 inch.

3.9.1.4 Final Backfill

Fill the remainder of the trench, except for special materials for roadways, and railroads with satisfactory material. Place backfill material and compact as follows:

a. Roadways and Railroads: Place backfill up to the required elevation as specified. Do not permit water flooding or jetting methods of compaction.

3.9.2 Backfill for Appurtenances

After the manhole, catchbasin, inlet, or similar structure has been constructed and the concrete has been allowed to cure, place backfill in such a manner that the structure will not be damaged by the shock of falling earth. Deposit the backfill material, compact it as specified for final backfill, and bring up the backfill evenly on all sides of the structure to prevent eccentric loading and excessive stress.

3.10 SPECIAL REQUIREMENTS

Special requirements for both excavation and backfill relating to the specific utilities are as follows:

3.10.1 Water Lines

Excavate trenches to a depth that provides a minimum cover of 3 feet from the existing ground surface, or from the indicated finished grade, whichever is lower, to the top of the pipe.

3.10.2 Electrical Distribution System

Provide a minimum cover of 24 inches from the finished grade to direct burial cable and conduit or duct line, unless otherwise indicated.

3.10.3 Pipeline Casing

Provide new smooth wall steel pipeline casing under existing railroad by the boring and jacking method of installation. Provide each new pipeline casing, where indicated and to the lengths and dimensions shown, complete and suitable for use with the new piped utility as indicated. Install pipeline casing by dry boring and jacking method as follows:

3.10.3.1 Bore Holes

Mechanically bore holes and case through the soil with a cutting head on a continuous auger mounted inside the casing pipe. Weld lengths of pipe together in accordance with AWS D1.1. Do not use water or other fluids in connection with the boring operation.

3.10.3.2 Cleaning

Clean inside of the pipeline casing of dirt, weld splatters, and other foreign matter which would interfere with insertion of the piped utilities by attaching a pipe cleaning plug to the boring rig and passing it through the pipe.

3.10.3.3 End Seals

After installation of piped utilities in pipeline casing, provide watertight end seals at each end of pipeline casing between pipeline casing and piping utilities. Provide watertight segmented elastomeric end seals.

3.10.4 Rip-Rap Construction

Place rip-rap on filter fabric in the areas indicated. Install riprap to conform to cross sections, lines and grades shown within a tolerance of 0.1 foot.

3.10.4.1 Stone Placement

Place rock for rip-rap on prepared bedding material to produce a well graded mass with the minimum practicable percentage of voids in conformance with lines and grades indicated. Distribute larger rock fragments, with dimensions extending the full depth of the rip-rap throughout the entire mass and eliminate "pockets" of small rock fragments. Rearrange individual pieces by mechanical equipment or by hand as necessary to obtain the distribution of fragment sizes specified above.

3.11 EMBANKMENTS

3.11.1 Earth Embankments

Construct earth embankments from satisfactory materials free of organic or frozen material and rocks with any dimension greater than 3 inches. Place the material in successive horizontal layers of loose material not more than 10 inches in depth. Spread each layer uniformly on a soil surface that has been moistened or aerated as necessary, and scarified or otherwise broken up so that the fill will bond with the surface on which it is placed.

After spreading, plow, disk, or otherwise brake up each layer; moisten or aerate as necessary; thoroughly mix; and compact to at least 95 percent laboratory maximum density for cohesive materials (ASTM D 698) or 98 percent laboratory maximum density for cohesionless materials (ASTM D 698). Finish compaction by sheepsfoot rollers, pneumatic-tired rollers, steel-wheeled rollers, vibratory compactors, or other approved equipment.

3.11.1.1 Waste Cell Perimeter Embankment at Crescent Junction

The Waste Cell Perimeter Embankment forms the outside of the waste cell, and will have 3:1 interior slopes, 5:1 exterior slopes, and a 30 ft wide level top. Material from the cell excavation will be used to construct the Waste Cell Perimeter Embankment. The fill shall be tested to determine its maximum dry density in accordance with ASTM D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, and the moisture content shall be modified to bring the fill to near optimum for compaction.

Construct the Waste Cell Perimeter Embankment as follows:
1) Prepare the ground beneath the proposed perimeter embankment by stripping vegetation and loose soil from the site, scarifying and compacting the top six inches of soil.
2) Dump and spread fill in loose lifts of nearly uniform thickness, not to exceed 12" compacted. Fill shall be compacted with a minimum 45,000 lb static weight footed roller capable of kneading compaction, with feet a minimum of 6 inches in length.
3) At the Contractor's option, the compactor may be equipped with a Computer Aided Earthmoving System, and soil placement and compaction shall be controlled by the CAES.
4) Use the CAES to determine and document compaction, or perform soil density tests in accordance with Section 3.14, below.

3.11.1.2 Waste Cell Spoil Material Embankment at Crescent Junction

The Waste Cell Spoil Material Embankment is a fill embankment to be constructed north of the waste cell. The embankment will divert storm water from the Book Cliffs around the waste cell, and shall be constructed of surplus excavated material (spoil material) from the waste cell excavation. Prior to placement, spoil material shall be tested to determine its maximum dry density in accordance with ASTM D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, and the moisture content shall be modified to bring the fill to near optimum for compaction.

Construct the Waste Cell Spoil Material Embankment as follows:
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" compacted. Compact material with rollers, equipment tracks, or successive passes of scrapers. Fill shall be compacted to a density of 90% of the laboratory determined maximum density in accordance with ASTM D 698.
3) Perform soil density tests in accordance with Section 3.14, below.

3.12 SUBGRADE PREPARATION

3.12.1 Proof Rolling

Prior to the placement of fill or stone base material perform proof rolling to identify soft soil areas. Proof roll the existing subgrade with rubber-tired construction equipment, such as a loaded dump truck or loaded scraper, with a minimum weight of 45,000 lbs. Notify the Construction Manager a minimum of 3 days prior to proof rolling. Perform proof rolling in the presence of the Construction Manager. Undercut rutting or pumping of material as directed by the Construction Manager to a depth of 12 inches and replace with select material.

3.12.2 Construction

Shape subgrade to line, grade, and cross section, and compact as specified. Include plowing, disking, and any moistening or aerating required to obtain specified compaction for this operation. Remove soft or otherwise unsatisfactory material and replace with satisfactory excavated material or other approved material as directed. Excavate rock encountered in the cut section to a depth of 6 inches below finished grade for the subgrade. Bring up low areas resulting from removal of unsatisfactory material or excavation of rock to required grade with satisfactory materials, and shape the entire subgrade to line and grade, in accordance with project plans.

3.12.3 Compaction

Finish compaction by sheepsfoot rollers, pneumatic-tired rollers, steel-wheeled rollers, vibratory compactors, or other approved equipment. Except for paved areas and railroads, compact each layer of the embankment to at least 95 percent of laboratory maximum density (ASTM D 1557).

3.12.3.1 Subgrade for Railroads

Compact subgrade for railroads to at least 95 percent laboratory maximum density for cohesive materials or 98 percent laboratory maximum density for cohesionless materials (ASTM D 1557).

3.12.3.2 Subgrade for Pavements

Compact subgrade for pavements to at least 95 percent laboratory maximum density (ASTM D 1557) for the depth below the surface of the pavement shown. When more than one soil classification is present in the subgrade, thoroughly blend, reshape, and compact the top 6 inches of subgrade.

3.13 FINISHING

Finish the surface of excavations, embankments, and subgrades to a smooth and compact surface in accordance with the lines, grades, and cross sections or elevations shown. Provide the degree of finish for graded areas within 0.1 foot of the grades and elevations indicated except that the degree of finish for subgrades specified in paragraph SUBGRADE PREPARATION. Finish gutters and ditches in a manner that will result in effective drainage. Finish the surface of areas to be turfed from settlement or washing to a smoothness suitable for the application of turfing materials. Repair graded, topsoiled, or backfilled areas prior to acceptance of the work, and re-established grades to the required elevations and slopes.

3.13.1 Subgrade and Embankments

During construction, keep embankments and excavations shaped and drained. Maintain ditches and drains along subgrade to drain effectively at all times. Do not disturb the finished subgrade by traffic or other operation.

The Contractor is responsible for protecting and maintaining the finsihed subgrade in a satisfactory condition until ballast, subbase, base, or pavement is placed. Do not permit the storage or stockpiling of materials on the finished subgrade. Do not lay subbase, base course, ballast, or pavement until the subgrade has been checked and approved, and in no case place subbase, base, surfacing, pavement, or ballast on a muddy, spongy, or frozen subgrade.

3.13.2 Capillary Water Barrier

Place a capillary water barrier under concrete floors and slabs directly on the subgrade and compact with a minimum of two passes of a vibratory compactor.

3.13.3 Grading Around Structures

Construct areas within 5 feet outside of each building and structure line true-to-grade, shape to drain, and maintain free of trash and debris until final inspection has been completed and the work has been accepted.

3.14 TESTING

Determine field in-place density in accordance with ASTM D 6938. When ASTM D 6938 is used, check the calibration curves and adjust using only the sand cone method as described in ASTM D 1556. Check the calibration of both the density and moisture gauges at the beginning of a job on each different type of material encountered and at intervals as directed by the Construction Manager. When test results indicate, that compaction is not as specified, remove the material, replace and recompact to meet specification requirements. Perform tests on recompacted areas to determine conformance with specification requirements. Provide certified test results that state that the tests and observations were performed by or under the direct supervision of the engineer and that the results are representative of the materials or conditions being certified by the tests. The following number of tests, if performed at the appropriate time, will be the minimum acceptable for each type operation.

3.14.1 In-Place Densities

a. One test per 5,000 square feet, or fraction thereof, of each lift of fill or backfill areas compacted by other than hand-operated machines.

b. One test per 500 square feet, or fraction thereof, of each lift of fill or backfill areas compacted by hand-operated machines.

3.14.1.1 In-Place Density Testing of Waste Cell Perimeter Embankment

a. 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.

b. For material compacted by hand-operated machines: One test per 500 square feet, or fraction thereof, of each lift of fill or backfill areas.

3.14.1.2 In-Place Density Testing of Waste Cell Spoil Material Embankment

a. For material compacted by other than hand-operated machines: One test per 100,000 square feet or 3,700 cubic yards of material placed.

b. For material compacted by hand-operated machines: One test per 500 square feet, or fraction thereof, of each lift of fill or backfill areas.

3.14.2 Check Tests on In-Place Densities

If ASTM D 6938 is used, check in-place densities by ASTM D 1556 as follows:

a. One check test for each 20 tests per ASTM D 6938, of fill or backfill compacted by other than hand-operated machines.

b. One check test for each 10 tests per ASTM D 6938, of fill or backfill compacted by hand-operated machines.

3.14.3 Optimum Moisture and Laboratory Maximum Density

Perform Laboratory Density and Moisture Content tests (ASTM D 698, ASTM D 1557, and ASTM D 2216) for each type of fill material to determine the optimum moisture and laboratory maximum density values. For small fill areas of 50,000 cubic yards of fill or less, perform one representative test per 5,000 cubic yards of fill and backfill, or when any change in material occurs that may affect the optimum moisture content or laboratory maximum density. For fill areas requiring more than 50,000 cubic yards of fill, perform one representative test per 20,000 cubic yards of fill and backfill, or when any change in material occurs that may affect the optimum moisture content or laboratory maximum density.

3.14.4 Moisture Control

In the stockpile, excavations, or borrow areas, perform moisture tests per 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 mositure content by one of the following tests:

o ASTM D 2216 - Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
o ASTM D 4643 - Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
o ASTM D 4944 - Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
o ASTM D 4959 - 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.

3.15 DISPOSITION OF SURPLUS MATERIAL

Surplus material or other soil material not required or suitable for filling or backfilling, and brush and refuse, shall be removed from Government property or disposed of on site as directed by the Construction

Manager.

-- End of Section --

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MOAB UMTRA PROJECT MOAB, UTAH PROJECT NO: 35DJ2600	DOCUMENT NO.: 35DJ2600-056-SPEC-31-00-20
	SECTION NO.: 31-00-20
	PLACEMENT AND COMPACTION OF TAILINGS AND INTERIM COVER

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	01/30/08	WDB	FMP	W. Barton	ALL	Page 5, Section 1.3.2: Added Dozers Page 6, Section 3.2.1: Revised Lift Thickness Page 7, Section 3.4.1: Revised Test Frequencies
2	02/27/08	WDB WDB	FMP FMP	W. Barton WDB	ALL	Page 6, Section 2.2: Removed requirement to screen material.

REGISTERED PROFESSIONAL ENGINEER
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FRANKLIN M. PARTON JR.

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DIVISION 31 - EARTHWORK

SECTION 31 00 20

PLACEMENT AND COMPACTION OF TAILINGS AND INTERIM COVER

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SECTION 31 00 20

PLACEMENT AND COMPACTION OF TAILINGS AND INTERIM COVER

PART 1 GENERAL

This specification covers placement, compaction and testing requirements for tailings material and interim clean cover layers at Crescent Junction.

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D 698	(2000ae1) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu ft)
ASTM D 1140	(2000) Amount of Material in Soils Finer than the No. 200 (75-micrometer) Sieve
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 1557	(2002e1) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/cu ft)
ASTM D 1587	(2000) Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
ASTM D 2167	(1994; R 2001) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D 2216	(2005) Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 2488	(2006) Description and Identification of Soils (Visual-Manual Procedure)
ASTM D 2922	(2005) Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
ASTM D 3017	(2005) Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)
ASTM D 3740	(2004a) Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

ASTM D 422	(1963; R 2002e1) Particle-Size Analysis of Soils
ASTM D 4220	(1995; R 2000) Preserving and Transporting Soil Samples
ASTM D 4318	(2005) Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
ASTM D 4944	(2004) Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by Direct Heating
ASTM D 6938	(2007b) In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

1.2 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Protection

Equipment

Materials Handling Plan describing the following: processing and placement of the soil; type, model number, weight and critical dimensions of equipment to be used for soil processing, compaction, scarification, and smooth rolling; method of protecting fill materials from changes in moisture content and freezing after placement.

Testing Laboratory

Name and qualifications of the proposed testing laboratory.

SD-06 Test Reports

Tailings/Fill Material Testing

Compaction Testing

Within 24 hours of conclusion of physical tests, 3 copies of test results, including calibration curves and results of calibration tests.

1.3 EQUIPMENT

Tailings and interim fill material shall be installed with equipment capable of scarifying and preparing the ground surface to receive fill, spreading fill material in uniform lifts, and compacting it to the density required by this specification.

1.3.1 Scarification Equipment

Disks, tillers, or other approved means shall be provided to scarify the the ground surface or the surface of each previous lift of fill prior to placement of the next lift. The scarification equipment shall be capable of uniformly disturbing the upper 1 inch of the underlying soil surface to provide good bonding between lifts.

1.3.2 Compaction Equipment

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 which would impair the effectiveness of the tamping foot rollers. Dozers shall have a minimum ground pressure of 1,650 lbs per sq ft.

1.3.3 Steel Wheeled Rollers

A smooth, non-vibratory steel wheeled roller shall be used to produce a smooth compacted surface on the top of the completed interim cover layer, such that direct rainfall causes minimal erosion. Steel wheeled rollers shall weigh a minimum of 20,000 pounds.

1.3.4 Hand Operated Tampers

Hand operated tampers shall consist of rammers or other impact type equipment. Vibratory type equipment will not be allowed.

PART 2 PRODUCTS

2.1 TAILINGS MATERIAL

Tailings material will consist of uranium mill tailings from the Moab Tailings Pile, off-pile contaminated soils, and demolition debris and other waste materials stored in the Pile at Moab. Most of the material will be uranium mill tailings, consisting of contaminated sands, slimes, intermediate material, and cover soil. The tailings material will be excavated, mixed and blended, dried to near optimum moisture content for compaction, loaded in containers, and shipped to Crescent Junction for disposal. Off pile contaminated soil material will be excavated and hauled to the tailings pile and eventually mixed with the tailings. Demolition debris and other waste materials will be excavated, placed in containers, and shipped like the tailings material. In the waste cell, non-soil materials will be placed in the contaminated tailings fill in a manner that will not result in voids in the waste mass.

2.2 INTERIM COVER SOIL

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, organic or frozen material, and shall have a maximum clod size of 1 inch at the time of compaction. Interim cover material shall comply with the criteria listed in Table 1.

TABLE 1
REQUIRED PHYSICAL PROPERTIES OF INTERIM COVER SOIL

Property	Test Value	Test Method
Max. particle size (inches)	1	ASTM D 422
Min. percent passing No. 4 sieve	70	ASTM D 422
Min. percent passing No. 200 sieve	20	ASTM D 1140
Min. liquid limit	25	ASTM D 4318
Min. plasticity index	10	ASTM D 4318
Max. plasticity index	40	ASTM D 4318

PART 3 EXECUTION

3.1 TAILINGS AND FILL SOIL ASSESSMENT TESTS

Assessment tests shall be performed on Tailings and on Stockpiled soil for the Interim Cover Layer to assure compliance with specified requirements and to develop compaction requirements for placement. A minimum of three tests for maximum dry density (ASTM D 698) and moisture content (ASTM D 2216) shall be performed for each type of tailings soil observed. A minimum of three assessment tests shall be performed on stockpiled excavated material for use as Interim Cover Soil for each type of soil observed. During placement of Tailings and Interim Cover soil, quick moisture content tests (ASTM D 4643, ASTM D 4944, or ASTM D 4959) shall be performed as required to maintain moisture control.

3.1.1 Compaction Testing

A representative sample from each principal type or combination of blended Tailings materials shall be tested to establish compaction curves using ASTM D 698. A minimum of one set of compaction curves shall be developed per 10,000 cubic yards of Tailings material. A minimum of 5 points shall be used to develop each compaction curve. A representative sample from each type or combination of stockpiled excavated soil for use as Interim Cover soil shall be tested to establish compaction curves using ASTM D 698.

3.2 INSTALLATION

3.2.1 Tailings and Interim Cover Soil Placement

Tailings and Interim Cover soil shall be placed to the lines and grades shown on the drawings. A GPS guided Computer Aided Earthmoving System (CAES) shall be used to direct fill placement such that Tailings and Interim Cover Soil are placed in loose lifts not to exceed 12 inches in thickness after compaction. In areas where hand operated tampers must be used, the loose lift thickness shall not exceed 4 inches.

3.2.2 Moisture Control

Tailings and Interim Cover shall be placed and compacted within the moisture content range needed to achieve 90% of the laboratory determined maximum dry density of each type of material. The moisture content shall be maintained uniform throughout each lift. Material shall be dried or water added and thoroughly incorporated into the Tailings or Interim Cover Soil as needed to ensure uniformity of moisture content prior to compaction.

3.2.3 Compaction

Tailings and Interim Cover soil shall be compacted to meet the following density requirements:
Tailings - 90% of the laboratory determined maximum dry density as determined by (ASTM D 698).
Interim Cover Layer - 90% of the laboratory determined maximum dry density as determined by (ASTM D 698).

3.2.4 Scarification

Scarification shall be performed on all areas of the upper surface of each lift prior to placement of the next lift. Scarification shall be accomplished with approved equipment. The final lift of Interim Cover soil shall not be scarified. The final lift shall be smooth rolled with at least 3 passes of the smooth steel wheeled roller to provide a smooth surface.

3.2.5 Placement of Demolition Debris

Demolition debris will be placed in the waste cell along with Tailings material. 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.

3.3 CONSTRUCTION TOLERANCES

The top surface of the Tailings and Interim Cover Layer shall be no greater than 2 inches above the lines and grades shown on the drawings. No minus tolerance will be permitted.

3.4 CONSTRUCTION TESTS

3.4.1 Tailings and Interim Cover Layer Tests

Compaction shall be verified by the CAES. When compaction of a lift of Tailings or Interim Cover soil is achieved, the CAES will produce a map of the location and thickness of the completed lift. Computer records for each layer of soil placed will constitute documentation of completed lifts and be compiled as contruction records.

Perform compaction Verification Tests, in-place density and moisture content tests on compacted fill material, in accordance with the following requirements:
- Verification tests of in-place density shall be performed on the initial layer of Tailings, on the first 5,000 cubic yards of Interim Cover, and on any layers in which the CAES indicates that problems occurred obtaining compaction.

- 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 of fill material placed.
- Compaction and moisture content tests shall be performed in accordance with the following methods:
  - o ASTM D 1556 - Density and Unit Weight of Soil in Place by the Sand-Cone Method
  - o ASTM D 2216 - Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
  - o ASTM D 6938 - In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

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

3.4.2 Quick Moisture Tests

Each day that Tailings or Interim Cover soil are being placed, a minimum of one moisture content quick test in accordance with (ASTM D 4643, ASTM D 4944, or ASTM D 4959) shall be performed to maintain moisture control during fill placement.

3.4.3 Test Results

Where the CAES indicates acceptable compaction, the computer output for that lift (lift thickness, location, and compaction), shall be considered proof of satisfactory lift placement. If the CAES indicates that adequate compaction is not achieved, the lift shall be reworked until an acceptable result is achieved. Verification test results of ASTM D 6938, In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth), shall be used to confirm the acceptability of the CAES results.

3.5 PROTECTION

3.5.1 Moisture Content

After lift placement, moisture content shall be maintained until the next lift is placed.

3.5.2 Erosion

Erosion that occurs in the Tailings or Interim Cover layers shall be repaired and grades re-established.

3.5.3 Freezing and Desiccation

Freezing and desiccation of the Tailings and Interim Cover soil shall be prevented. If freezing or desiccation occurs, the affected soil shall be reconditioned as directed.

3.5.4 Retests

Areas that have been repaired shall be retested as directed. Repairs to the Tailings or Interim Cover layers shall be documented including location and volume of soil affected, corrective action taken, and results of retests.

-- End of Section --

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MOAB UMTRA PROJECT MOAB, UTAH PROJECT NO: 35DJ2600	DOCUMENT NO.: 35DJ2600-056-SPEC-31-00-30
	SECTION NO.: 31-00-30
	PLACEMENT AND COMPACTION OF FINAL CAP LAYERS

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	1/30/08	WDB WDB	FMP	W. Barton W. Barton	ALL	Page 7, Section 3.2.2: Revised lift thickness Page 8, Section 3.2.6: Added bentonite Page 8, Section 3.3.2: Revised lift thickness Page 9, Section 3.3.6: Added bentonite Page 9, Section 3.4.1: Revised final sentence.

REGISTERED PROFESSIONAL ENGINEER
No. 6785479-2202
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SECTION TABLE OF CONTENTS

DIVISION 31 - EARTHWORK

SECTION 31 00 30

PLACEMENT AND COMPACTION OF FINAL CAP LAYERS

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SECTION 31 00 30

PLACEMENT AND COMPACTION OF FINAL CAP LAYERS

PART 1 GENERAL

1.1 SCOPE

This specification covers material characteristics, placement, compaction, and testing of final cap layers, including:
- Radon barrier layer;
- Stone infiltration and bio-barrier;
- Frost protection layer; and
- Rock armoring.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D 1140	(2000) Amount of Material in Soils Finer than the No. 200 (75-micrometer) Sieve
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 698	(2002e1) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu ft)
ASTM D 2167	(1994; R 2001) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D 2216	(2005) Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 2488	(2006) Description and Identification of Soils (Visual-Manual Procedure)
ASTM D 6938	(2007b) In-place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D 3740	(2004a) Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
ASTM D 422	(1963; R 2002e1) Particle-Size Analysis of Soils

ASTM D 4220	(1995; R 2000) Preserving and Transporting Soil Samples
ASTM D 4318	(2005) Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
ASTM D 4944	(2004) Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by Direct Heating

1.3 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Equipment

Submit specifications for equipment for the processing, scarification, placement, compaction, and smooth rolling of fill, including type, model number, weight and critical dimensions of equipment.

SD-06 Test Reports

Moisture Content and Relative Density Tests of Fill Materials, G;

Moisture Content Tests of Soil Fill, G;

Moisture Content and In-Place Density Tests of Soil Fill (Verification Testing), G;

CAES Soil Placement and Compaction Records, G;

Test reports shall be submitted to the Energy Solutions Construction Quality Control Manager within 48 hours of the completion of soil placement and field testing.

1.4 EQUIPMENT

Equipment used to place and compact the Radon Barrier material and Frost Protection common fill shall not brake suddenly, turn sharply, or be operated at excessive speeds.

1.4.1 Compaction Equipment

Compaction equipment shall consist of footed rollers which have a minimum weight of 45,000 pounds and at least one foot for each 110 square inches of drum surface. The length of each tamping foot shall be at least 6 inches, from the outside surface of the drum. During compaction operations, the spaces between the tamping feet shall be maintained clear of materials which would impair the effectiveness of the tamping foot rollers.

1.4.2 Scarification Equipment

Disks, rotor tillers, or other approved means shall be provided to scarify the surface of each lift of soil prior to placement of the next lift. The scarification equipment shall be capable of uniformly disturbing the upper 1 - 2 inches of the soil surface to provide good bonding between lifts.

1.4.3 Steel Wheeled Rollers

A smooth, non-vibratory steel wheeled roller shall be used to produce a smooth compacted surface on finished compacted soil layers. Steel wheeled rollers shall weigh a minimum of 20,000 pounds.

1.4.4 Hand Operated Tampers

Hand operated tampers shall consist of rammers or other impact type equipment. Vibratory type equipment will not be allowed.

PART 2 PRODUCTS

2.1 RADON BARRIER LAYER

Radon Barrier is the layer constructed on top of the interim cover layer and the contaminated tailings material in the waste cell and underlying the protection layers in the final cap. The purpose of this layer is to retard the emanation of radon gas from the tailings into the atmosphere and to minimize infiltration of incident precipitation into the tailings material.

Radon Barrier Layer soil shall be produced by modifying the weathered Mancos Shale excavated on site. Weathered Mancos Shale shall be excavated, separated from other excavated materials, pulverized, wetted, and mixed to produce a uniform fine-grained fill soil at or above optimum moisture content for compaction. It shall be free of roots, debris, organic or frozen material, and shall have a maximum clod size of 1 inch at the time of compaction. Fill material shall comply with the criteria listed in Table 1. Testing of Radon Barrier soil to verify conformance with the following table is described in Section 3.2.1 Radon Barrier Material.

TABLE 1
REQUIRED PHYSICAL PROPERTIES OF RADON BARRIER FILL SOIL

Property	Test Value	Test Method
Max. particle size (inches)	1	ASTM D 422
Min. percent passing No. 4 sieve	80	ASTM D 422
Min. percent passing No. 200 sieve	50	ASTM D 1140
Min. liquid limit	35	ASTM D 4318
Min. plasticity index	10	ASTM D 4318
Max. plasticity index	40	ASTM D 4318

2.2 STONE FOR FINAL COVER LAYERS

Stone for the final cover layers, infiltration and bio-barrier layer and rock armoring, shall be rock material that has long-term chemical and physical durability. Rock for final cover layers shall achieve an accpetable score for its intended use, in accordance with the following rock scoring and acceptance criteria:

TABLE 2
NRC TABLE OF SCORING CRITERIA FOR ROCK QUALITY

Laboratory Test	Weighing Factor													
	L*	S*	I*	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair				Poor		
Specific Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.30	2.25
Absorption, %	13	5	2	0.10	0.30	0.50	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
LA Abrasion, %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmitt Hammer	11	13	3	70	65	60	54	47	40	32	24	16	8	0

* L = Limestone, S = Sandstone, I = Igneous

Notes:
1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642, Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, 1982.
2. Weighing Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G.W. Dupuy, Engineering Geology, July 1965. Weighing factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighing factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR2642, so that proper correlations can be made.

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

Oversize rock as follows;
- Subtract the rock score from 80% to determine the amount of oversizing required. For example, a rock with a rating of 70% will require oversizing of 10 percent (80% - 70% = 10%).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10% 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.

2.3 FROST PROTECTION LAYER

The Frost Protection Layer is the top soil layer constructed of the waste cell cover. The purpose of this layer is to protect underlying cover layers from degradation due to environmental factors such as freeze-thaw cycles. The Frost Protection Layer shall be constructed of common fill material, which can be any soil material from the waste cell excavation.

PART 3 EXECUTION

3.1 EXCAVATION, SEGREGATION, AND STOCKPILING OF CAP MATERIALS

Cap materials shall be soil material from the waste cell excavation. Materials shall be excavated, segregated into common fill and weathered Mancos Shale, and stockpiled for use as cap materials. Stockpiles shall be at locations shown in the project plans or as directed by the Construction Manager.

3.2 INSTALLATION OF RADON BARRIER MATERIAL

3.2.1 Radon Barrier Material

The Radon Barrier Layer will be constructed of processed Mancos Shale soil. The soil will be produced on site by processing excavated Mancos Shale into a fine-grained soil and adding water to bring the Mancos Shale soil to near optimum moisture content for compaction. Mancos Shale soil produced for Radon Barrier fill shall be tested to determine its material properties and its maximum dry density and moisture content. As a minimum, perform the following soil tests on each 10,000 cu yds of soil:

ASTM D 4318, Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 1140, Amount of Material in Soils Finer than the No. 200 Sieve
ASTM D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.
ASTM D 2216, Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass and/or ASTM D 4643, Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

3.2.2 Radon Barrier Material Placement

Radon Barrier shall be placed to the lines and grades shown on the drawings. The soil shall be placed in loose lifts not to exceed 12 inches in thickness after compaction. In areas where hand operated tampers must be used, the loose lift thickness shall not exceed 4 inches.

3.2.3 Moisture Control

Radon Barrier soil shall be placed and compacted within a moisture content range that will achieve the specified compaction. The moisture content shall be maintained uniform throughout each lift. Water added shall be thoroughly incorporated into the soil to ensure uniformity of moisture content prior to compaction.

3.2.4 Scarification and Dressing of Final Lift Surface

Scarification shall be performed on all areas of the upper surface of each underlying soil layer prior to placement of the next lift. Scarification shall be accomplished with approved equipment. The final lift of Radon Barrier soil shall not be scarified. The final lift shall be smooth rolled with at least 3 passes of the approved smooth steel wheeled roller to provide a smooth surface.

3.2.5 Compaction

Radon Barrier soil shall be compacted to at least 95% of its laboratory determined maximum dry density. The Computer Aided Earthmoving System shall be used to direct fill placement, monitor compaction, and record the location and thickness of each soil layer being placed.

3.2.6 Repair of Voids

Voids created in the Radon Barrier layer during construction (including, but not limited to, penetrations for test samples, grade stakes, and other penetrations necessary for construction) shall be repaired by removing any unsuitable material, backfilling with soil and compacting by tamping each lift with a steel rod, or by backfilling with bentonite.

3.3 INSTALLATION OF FROST PROTECTION LAYER SOIL

3.3.1 Frost Protection Material

The Frost Protection layer will be constructed of common fill soil. The soil will be produced on site by adding water to bring the excavated and stockpiled soil to near optimum moisture content for compaction. Test soil in accordance with ASTM D 698, Laboratory Compaction Characteristics of Soil Using Standard Effort. Perform at least 3 tests on each type of material stockpiled for use as fill. Perform additional lab density tests on stockpiled material if changes in material characteristics are observed.

3.3.2 Frost Protection Layer Placement

Frost Protection soil shall be placed to the lines and grades shown on the drawings. The soil shall be placed in loose lifts not to exceed 12 inches in thickness after compaction. In areas where hand operated tampers must be used, the loose lift thickness shall not exceed 4 inches.

3.3.3 Moisture Control

Frost Protection soil shall be placed and compacted within a moisture content range that will achieve the specified compaction. The moisture content shall be maintained uniform throughout each lift. Water added shall be thoroughly incorporated into the soil to ensure uniformity of moisture content prior to compaction.

3.3.4 Scarification and Dressing of Final Lift Surface

Scarification shall be performed on all areas of the upper surface of each underlying soil layer prior to placement of the next lift. Scarification shall be accomplished with approved equipment. The final lift of soil shall not be scarified. The final lift shall be smooth rolled with at least 3 passes of the approved smooth steel wheeled roller to provide a smooth surface.

3.3.5 Compaction

Soil shall be compacted to 90% of the laboratory determined maximum dry density in accordance with ASTM D 698. The Computer Aided Earthmoving System shall be used to direct fill placement, monitor compaction, and record the location and thickness of each soil layer being placed.

3.3.6 Repair of Voids

Voids created in the Radon Barrier layer during construction (including, but not limited to, penetrations for test samples, grade stakes, and other penetrations necessary for construction) shall be repaired by removing any unsuitable material, backfilling with soil and compacting by tamping each lift with a steel rod, or by backfilling with bentonite.

3.4 INSTALLATION OF ROCK LAYERS

This section describes the material and installation of rock layers for the Infiltration and Biobarrier and Rock Armoring of the final cover.

3.4.1 Rock Placement and Compaction

Rock shall be spread to the thickness indicated on the drawings or in accordance with oversizing due to scoring criteria (see Section 2.2 of this specification). Rock placement shall be guided by the Computer Aided Earthmoving System to ensure that the appropriate thickness has been placed at all locations. Stone with a D50 of 2 inches or less shall be shall be compacted with a vibratory steel drum.

3.5 CONSTRUCTION TOLERANCES

The top surface of the each layer shall be no greater than 2 inches above the lines and grades shown on the drawings. No minus tolerance will be permitted.

3.6 CONSTRUCTION TESTS

3.6.1 Material Tests

For placement and compaction of soils, moisture content tests shall be performed daily prior to placement to maintain moisture control and uniformity of soil to be used for fill. Computer Aided Earthmoving System shall be used to place, compact and document compaction of all soil layers. CAES acceptance of an installed layer of soil will constitute proof of satisfactory compaction. Computer output of the CAES will be acceptable documentation for location, thickness and compaction of installed layers.

Compaction Verification Tests - Perform in-place density and moisture content tests on compacted fill material in accordance with the following requirements:

- Verification tests of in-place density shall be performed on initial layer of soil placed, and on any layers in which the CAES indicates that problems occurred obtaining compaction.
- 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 of fill material placed.
- Compaction and moisture content tests shall be performed in accordance with the following methods:

ASTM D 1556 - Density and Unit Weight of Soil in Place by the Sand-Cone Method

ASTM D 2216 - Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

ASTM D 6938(2007b) - In-place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

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

3.6.2 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. Prior to placement of the Radon Barrier Layer, a survey shall be performed of the top of the Interim Cover layer. 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.

3.7 PROTECTION

3.7.1 Moisture Content

After placement, moisture content shall be maintained or adjusted to meet criteria.

3.7.2 Erosion

Erosion that occurs in the fill layers shall be repaired and grades re-established.

3.7.3 Freezing and Desiccation

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.

3.7.4 Retests

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.

-- End of Section --

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MOAB UMTRA PROJECT **MOAB, UTAH** **PROJECT NO: 35DJ2600**	DOCUMENT NO.: 35DJ2600-056-SPEC-31-32-11
	SECTION NO.: 31-32-11
	SURFACE WATER MANAGEMENT AND EROSION CONTROL

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	1/30/08	WDB WDB	FMP	W.Barton W. Bart	ALL	Page 4, Sections 2.3 and 3.1: Added a tackifier or crusting agent for erosion control.

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DIVISION 31 - EARTHWORK

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SURFACE-WATER MANAGEMENT AND EROSION CONTROL

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SECTION 31 32 11

SURFACE-WATER MANAGEMENT AND EROSION CONTROL

PART 1 GENERAL

1.1 SCOPE

This section includes materials and placement of silt fence, erosion mat, check dams, construction entrances, diversions, ditches, channels, berms, and stabilization; and maintenance of sedimentation basins and surface-water management and erosion control measures.

1.2 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Manufacturer's data on silt fence;

Manufacturer's data on erosion control matting;

SD-08 Manufacturer's Instructions

Manufacturer's installation and maintenance instructions;

PART 2 PRODUCTS

2.1 SILT FENCE

Furnish silt fence with either woven or nonwoven geotextile. Silt fence shall be:

a. Woven geotextile consisting of slit films of polypropylene treated with ultraviolet light stabilizers, or nonwoven geotextile consisting of long chain polymeric filaments or polyester yarns, inert to chemicals commonly found in soils and to hydrocarbons, and resistant to mildew, rot, insects, and rodent attack.

b. Reinforcement Backing: Shall be minimum 14-gauge steel wire and maximum mesh spacing of 6 inches or synthetic netting of equal strength. Use reinforcemtne backing can be eliminated if post spacing is a maximum of 6 feet and the geotextile tensile strength is at least 200 pounds.

c. Posts: Shall be either wood or steel with minimum length of 4 feet. Wood posts shall be at least 2 inches by 2 inches of oak or similar hardwood. Steel posts shall be round or shaped as a "U", "T", or "C". Steel posts shall have a minimum weight of 1.33 pounds per linear foot and shall have projections for fastening reinforcement to silt fence.

d. Wire Staples: Shall be at least 9-gauge thickness with a minimum length of 1 inch.

e. A preassembled silt fence meeting the material requirements may be used instead of a field constructed silt fence.

2.2 EROSION MAT

Furnish erosion mat that shall be a woven blanket-like fabric made of biodegradable yarn with the following material properties:

a. Material Content: Coir Yarn: 100 percent; containing 45% Lignin, 55% Cellulose (approximately)

b. Weight: Minimum 22.7 ounces per square yard;

c. Open Area: 38 percent (approximately); and

d. Average Mesh Opening: 0.4" X 0.5"

Furnish erosion mat that will resist degradation for a minimum 6-month period after installation.

Furnish erosion mat having a permissible velocity of 7 ft per second.

2.3 OTHER MATERIALS

a. Culverts shall be in accordance with Section 33 40 01 STORM DRAINAGE.

b. Construction entrances shall be in accordance with design plans and details.

c. Tackifiers or crusting agents shall be used to reduce soil erosion as directed by the Construction Manager.

d. Materials for other surface-water management and erosion controls shall be in accordance with design plans and details.

2.4 EQUIPMENT

Furnish equipment to perform work specified in this section.

PART 3 EXECUTION

3.1 INSTALLATION

a. Install silt fence in accordance with Manufacturer's Instructions.

b. Install check dams in ditches and channels in accordance with project plans and details.

c. Tackifiers or crusting agents shall be applied in accordance with manufacturer's application instructions.

d. Construct channels, ditches, and other earthwork as shown on the construction drawings and in accordance with the Contractor's Surface-Water Management and Erosion Control Work Plan. Earthwork for channels, ditches, and berms shall be in accordance with Section 31 00 00 EARTHWORK.

3.2 ADDITIONAL REQUIREMENTS

Prevent the runoff of polluting substances such as silt, clay, fuels, oils, and contaminated soils from migrating into water supplies and surface waters.

Remove accumulated silt and debris from behind the face of the silt fence when the silt deposits reach approximately one half the height of the fence. Replace silt fence geotextile damaged during maintenance operations. Removed silt and debris shall be placed in locations approved by the Construction Manager.

3.3 MAINTENANCE

Clean, maintain, repair, and replace surface-water management and erosion controls for the duration of the contract in accordance with the Contractor's Surface-Water Management and Erosion Control Work Plan.

3.4 INSPECTIONS

Inspect surface-water management and erosion control measures and sedimentation basins to evaluate their effectiveness and need for maintenance. Any required repairs to the surface-water management and erosion control measures and sedimentation basins shall be initiated upon discovery, but no later than 24 hours after discovery. Inspections shall occur, at a minimum, at the following frequencies:

a. Weekly

b. Daily after each rain event exceeding 0.5 in.

c. Daily during prolonged rainfall events.

Records of inspections shall be kept on file on site by Contractor and shall be submitted monthly to the Construction Manager. The records of inspection shall include the following:

a. Summary of the scope of the inspection.

b. Name of inspector.

c. Inspection date.

d. Inspection location.

e. Purpose of the inspection (e.g., regular weekly, following a storm, etc.).

f. Observations relative to performance of the surface-water management and erosion control measures.

g. Any necessary corrective actions.

h. Corrective actions completed and their performance since the previous inspection.

-- End of Section --

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MOAB UMTRA PROJECT **MOAB, UTAH** **PROJECT NO: 35DJ2600**	DOCUMENT NO.: 35DJ2600-056-SPEC-32-11-23
	SECTION NO.: 32-11-23
	AGGREGATE AND RIPRAP

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	1/30/08	WDB	FMP	W. Barton	ALL	Page 11, Table 3, Revised Gradations to allow small amount of fines
2	2/27/08	WDB WDBE	FMP FMP	W. Barton WDB	ALL	Page 8, Section 1.5, Revised weather limitations. Page 11, Section 2.1.6.2, revised riprap thicknesses.

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SECTION 32 11 23

AGGREGATE AND RIPRAP

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO T 11 (2005) Standard Method of Test for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO T 19 (2004) Standard Method of Test for Bulk Density ("Unit Weight") and Voids in Aggregate

AASHTO T 27 (2006) Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates

AASHTO T 89 (2002) Standard Method of Test for Determining the Liquid Limit of Soils

AASHTO T 90 (2004) Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils

AASHTO T 99 (2001; R 2004) Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in) Drop

AASHTO T 180 (2004) Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in) Drop

AASHTO T 193 (2003) Standard Method of Test for The California Bearing Ratio

AASHTO T 224 (2001; R 2004) Correction for Coarse Particles in the Soil Compaction Test

ASTM INTERNATIONAL (ASTM)

ASTM C 1260 (2005a) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

ASTM C 127 (2004) Standard Test Method for Density,

	Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
ASTM C 128	(2004a) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C 131	(2006) Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 29/C 29M	(1997; R 2003) Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
ASTM C 88	(2005) Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM D 698	(2000ae1) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu ft)
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 1557	(2002e1) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3) (2700 kN-m/m3)
ASTM D 2167	(1994; R 2001) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D 2487	(2006) Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 6938	(2007b) In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D 75	(2003) Standard Practice for Sampling Aggregates
ASTM E 11	(2004) Wire Cloth and Sieves for Testing Purposes

1.2 DEFINITIONS

For the purposes of this specification, the following definitions apply.

1.2.1 Untreated Base Course

Untreated Base Course (UBC) is well graded, durable aggregate uniformly moistened and mechanically stabilized by compaction.

1.2.2 Degree of Compaction

Degree of compaction required, except as noted in the second sentence, is expressed as a percentage of the maximum laboratory dry density obtained by the test procedure presented in AASHTO T 99 or AASHTO T 180 abbreviated as a percent of laboratory maximum dry density. The degree of compaction for material having more than 30 percent by weight of their particles retained on the 3/4 inch sieve shall be expressed as a percentage of the laboratory maximum dry density in accordance with AASHTO T 99 or AASHTO T 180 Method D and corrected with AASHTO T 224.

1.3 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

Sampling and Testing, G;

Field Density Tests, G;

Certified copies of test results for approval not less than 10 days before material is required for the work.

Calibration curves and related test results prior to using the device or equipment being calibrated.

Copies of field test results within 24 hours after the tests are performed.

1.4 SAMPLING AND TESTING

Sampling and testing shall be the responsibility of the Contractor. The materials shall be tested to establish compliance with the specified requirements; testing shall be performed at the specified frequency. The Contracting Officer may specify the time and location of the tests. Copies of test results shall be furnished to the Contracting Officer within 24 hours of completion of the tests.

1.4.1 Sampling

Samples for laboratory testing shall be taken in conformance with ASTM D 75. When deemed necessary, the sampling will be observed by the Contracting Officer.

1.4.2 Tests

The following tests shall be performed in conformance with the applicable standards listed.

1.4.2.1 Sieve Analysis

Sieve analysis shall be made in conformance with AASHTO T 27 and AASHTO T 11. Sieves shall conform to ASTM E 11.

1.4.2.2 Liquid Limit and Plasticity Index

Liquid limit and plasticity index shall be determined in accordance with AASHTO T 89 and AASHTO T 90.

1.4.2.3 Moisture-Density Determinations

The laboratory maximum dry density and optimum moisture content shall be determined in accordance with AASHTO T 99 or AASHTO T 180, Method D and corrected with AASHTO T 224.

1.4.2.4 Field Density Tests

Density shall be field measured in accordance with ASTM D 1556, ASTM D 2167 or ASTM D 6938. For the method presented in ASTM D 6938 the calibration curves shall be checked and adjusted if necessary using only the sand cone method as described in paragraph Calibration, of the ASTM publication. Tests performed in accordance with ASTM D 6938 result in a wet unit weight of soil and when using this method, ASTM D 6938 shall be used to determine the moisture content of the soil. The calibration curves furnished with the moisture gauges shall also be checked along with density calibration checks as described in ASTM D 6938. The calibration checks of both the density and moisture gauges shall be made by the prepared containers of material method, as described in paragraph Calibration of ASTM D 6938, on each different type of material being tested at the beginning of a job.

1.4.2.5 Wear Test

Wear tests shall be made on aggregate material in conformance with ASTM C 131.

1.4.2.6 Soundness

Soundness tests shall be made on aggregate in accordance with ASTM C 88.

1.4.3 Testing Frequency

1.4.3.1 Tests on Proposed Material

To demonstrate that the proposed material meets all specified requirements, one of each of the following tests shall be performed on the proposed material prior to commencing construction, and subsequently for every 5,000 cubic yards of material. If materials from more than one source are going to be utilized, this testing shall be completed for each source.

a. Sieve Analysis.

b. Liquid limit and plasticity index.

c. Moisture-density relationship.

d. Wear.

e. Soundness.

1.4.4 Approval of Material

The source of the material shall be selected prior to the time the material will be required in the work. Approval of material will be based on test results.

1.5 WEATHER EFFECTS

Completed areas damaged by freezing, rainfall, or other weather conditions shall be corrected to meet specified requirements.

1.6 PLANT, EQUIPMENT, AND TOOLS

All plant, equipment, and tools used in the performance of the work shall be subject to approval before the work is started and shall be maintained in satisfactory working condition at all times. The equipment shall be adequate and shall have the capability of producing the required compaction, meeting grade controls, thickness control, and smoothness requirements as set forth herein.

PART 2 PRODUCTS

2.1 AGGREGATES

Aggregate shall consist of clean, sound, durable particles of crushed stone, crushed gravel, angular sand, or other approved material. Untreated Base Course shall be free of lumps of clay, organic matter, and other objectionable materials or coatings. Gravel shall be free of silt and clay as defined by ASTM D 2487, organic matter, and other objectionable materials or coatings. Aggregates will be used for the following applications, and the material properties for each of these application will be provided in the following section:

Application	**Name of Material**	**Gradation**
Road Base	Untreated Base Course	UDOT UBC
Pipe Bedding	Coarse sand/gravel	ASTM D448 #9
Drainage Stone	Open graded gravel	ASTM D448 #57
Riprap slope armor	Riprap	D50 per plans
Riprap channel armor	Riprap	D50 per plans
Cover Biobarrier	Sandy gravel	D50 2 in
Cover Top	Sandy gravel	D50 2 in
Cover Apron Riprap	Riprap, 1,000 yr	D50 per plans
Cover Slope Riprap	Riprap, 1,000 yr	D50 per plans
CJ Channel Armor	Riprap, 1,000 yr	D50 per plans

2.1.1 Road Base

Aggregate for road base beneath asphalt pavement and for unpaved gravel roads and pads shall be UDOT Untreated Base Course. The UBC coarse aggregate shall not show more than 50 percent loss when subjected to the Los Angeles abrasion test in accordance with ASTM C 131. The amount of flat and elongated particles shall not exceed 30 percent. A flat particle is one having a ratio of width to thickness greater than 3; an elongated particle is one having a ratio of length to width greater than 3. In the portion retained on each sieve specified, the crushed aggregates shall contain at least 50 percent by weight of crushed pieces having two or more freshly fractured faces with the area of each face being at least equal to 75 percent of the smallest midsectional area of the piece. When two fractures are contiguous, the angle between planes of the fractures must be at least 30 degrees in order to count as two fractured faces. Crushed gravel for road base shall be provided in the gradation listed in TABLE 1. When the coarse aggregate is supplied from more than one source, aggregate from each source shall meet the specified requirements and shall be stockpiled separately.

2.1.2 Pipe Bedding

Pipe bedding shall be coarse sand, or fine gravel, free from deleterious materials and rocks larger than 3/8 inch. Sandy soil or excavated shaly soil may be used for pipe bedding if it is excavated or processed such that the material size is similar to the gradation listed in TABLE 1.

2.1.3 Drainage Stone

Drainage stone is an open graded stone material intended as a capillary break beneath concrete slabs. Drainage stone will also be used for French Drains and seepage collection drains for retaining structures and mechanically stabilized earth structures. Drainage stone shall be provided in the gradation listed in TABLE 1.

2.1.4 Riprap

Riprap for slope and channel protection shall be provided at locations indicated on the drawings. Riprap shall be sized in accordance with plans and as listed in TABLE 1.

TABLE I. GRADATION OF AGGREGATES

Percentage by Weight Passing Square-Mesh Sieve

Sieve Designation	Road Base	Pipe Bedding	Drainage Stone	Riprap Slope Armor	Riprap Channel Armor
12 inch	-------	-------	-------	-------	100
10 inch	-------	-------	-------	100	80-100
8 inch	-------	-------	-------	80-100	20-80
6 inch	-------	-------	-------	20-60	0-20
4 inch	-------	-------	-------	0-20	0
2 inch	-------	-------	-------	0	-------
1-1/2 inch	100	-------	100	-------	-------
1 inch	90-100	-------	95-100	-------	-------
3/4 inch	70-85	-------	-------	-------	-------
1/2 inch	65-80	-------	25-60	-------	-------
3/8 inch	55-75	100	-------	-------	-------
No. 4	40-65	85-100	0-10	-------	-------
No. 8	-------	20-40	0-5	-------	-------
No. 16	25-40	10-20	0	-------	-------
No. 50	-------	5-10	-------	-------	-------
No. 200	7-11	0-5	-------	-------	-------

2.1.5 STONE FOR FINAL COVER LAYERS

Stone for the final cover layers, infiltration and bio-barrier layer and rock armoring, shall be rock material that has long-term chemical and physical durability. Rock for final cover layers shall achieve an accpetable score for its intended use, in accordance with the following rock scoring and acceptance criteria:

TABLE 2
NRC TABLE OF SCORING CRITERIA FOR ROCK QUALITY

Laboratory Test	Weighing Factor			10	9	8	7	6	5	4	3	2	1	0
	L*	S*	I*											

TABLE 2
NRC TABLE OF SCORING CRITERIA FOR ROCK QUALITY

					Good			Fair				Poor		
Specific Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.30	2.25
Absorption, %	13	5	2	0.10	0.30	0.50	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
LA Abrasion, %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmdt Hammer	11	13	3	70	65	60	54	47	40	32	24	16	8	0

* L = Limestone, S = Sandstone, I = Igneous

Notes:
1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642, Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, 1982.
2. Weighing Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G.W. Dupuy, Engineering Geology, July 1965. Weighing factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighing factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR2642, so that proper correlations can be made.

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

Oversize rock as follows;
- Subtract the rock score from 80% to determine the amount of oversizing required. For example, a rock with a rating of 70% will require oversizing of 10 percent (80% - 70% = 10%).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10% 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.

2.1.6 Stone Layers for the Waste Cell Final Cover

Stone shall be provided and installed for the following Final Cover Layers:

Application	**Type of Material**	**Material Size**
Cover Biobarrier	Sandy gravel	D50 2 in
Cover Top	Sandy gravel	D50 2 in
Cover South Edge	Riprap, 1,000 yr	D50 12"
Cover N,E,& W Edges	Riprap, 1,000 yr	D50 8"
CJ Channel Armoring	Riprap, 1,000 yr	D50 8"

2.1.6.1 Biobarrier and Cover Top

The Biobarrier and Top of Cover Stone shall meet the 1,000 year lifespan rock scoring criteria and shall be a mix of 2 inch stone and finer materials. The gradation shall be as listed in Table 3, below.

TABLE 3. GRADATION OF FINAL COVER AGGREGATES

Percentage by Weight Passing Square-Mesh Sieve

Sieve Designation	Cover Biobarrier	Cover Top	Cover South Edge Riprap & Bedding	Cover N, E, & W Edge Riprap & Bedding	Crescent Junct. Channel Armor Riprap
18 inch	-------	-------	100	-------	-------
16 inch	-------	-------	80-100	-------	-------
12 inch	-------	-------	30-60	100	100
10 inch	-------	-------	-------	80-100	80-100
8 inch	-------	-------	20-40	30-60	20-80
6 inch	-------	-------	0	20-40	0-20
4 inch	100	100	-------	0	0
2 inch	50-100	50-100	-------	-------	-------
1-1/2 inch	40-50	40-50	100	100	-------
1 inch	20-40	20-40	80-100	80-100	-------
3/4 inch	-------	-------	-------	-------	-------
1/2 inch	15-25	15-25	60-80	60-80	-------
3/8 inch	-------	-------	-------	-------	-------
No. 4	10-20	10-20	30-60	30-60	-------
No. 8	5-15	5-15	20-40	20-40	-------
No. 16	5-10	0-10	10-30	10-30	-------
No. 50	-------	-------	-------	-------	-------
No. 200	0-5	0-5	0-5	0-5	-------

2.1.6.2 Final Cover Edge Riprap

Riprap shall be placed on the Final Cover Edges in accordance with the locations and sizes shown on the Final Cover Plans. The Riprap must meet the 1,000 year lifespan rock scoring criteria. The Cover Edge consists of the slope of the Waste Cell and a 10 ft strip along the top of the slope. The South Edge riprap shall have a D50 of 12" and a bedding layer 4 inches in thickness. The East, West, and North edges shall have a D50 of 8" and a bedding layer 3 inches in thickness. Cover Edge stone gradations are listed in Table 3.

2.1.6.3 Channel Armor Riprap

Channel armor riprap for the channels associated with the Waste Cell shall have riprap armoring in locations and sizes shown in the Final Cover plans and gradation listed. The riprap must meet the 1,000 year lifespan rock scoring criteria. The channel armor riprap shall be installed without a bedding layer.

PART 3 EXECUTION

3.1 GENERAL REQUIREMENTS

Adequate drainage shall be provided during the entire period of construction to prevent water from collecting or standing on the working area. Line and grade stakes shall be provided as necessary for control.

3.2 OPERATION OF AGGREGATE SOURCES

Clearing, stripping, and excavating shall be the responsibility of the

Contractor. The aggregate sources shall be operated to produce the quantity and quality of materials meeting these specifications requirements in the specified time limit.

3.3 STOCKPILING MATERIAL

Prior to stockpiling of material, storage sites shall be cleared and leveled by the Contractor. All materials, including approved material available from excavation and grading, shall be stockpiled in the manner and at the locations designated. Aggregates shall be stockpiled on the cleared and leveled areas designated by the Contracting Officer to prevent segregation. Materials obtained from different sources shall be stockpiled separately.

3.4 PREPARATION OF UNDERLYING COURSE

Prior to constructing the base course(s), the underlying course or subgrade shall be cleaned of all foreign substances. At the time of construction of the base course(s), the underlying course shall contain no frozen material. The surface of the underlying course or subgrade shall meet specified compaction and surface tolerances. The underlying course shall conform to Section 31 00 00 EARTHWORK. Ruts or soft yielding spots in the underlying courses, areas having inadequate compaction, and deviations of the surface from the requirements set forth herein shall be corrected by loosening and removing soft or unsatisfactory material and by adding approved material, reshaping to line and grade, and recompacting to specified density requirements. The finished underlying course shall not be disturbed by traffic or other operations and shall be maintained by the Contractor in a satisfactory condition until the base course is placed.

3.5 INSTALLATION OF UNTREATED BASE COURSE

3.5.1 Placing

The material shall be placed on the prepared subgrade or subbase in layers of uniform thickness. When a compacted aggregate layer 6 inches or less in thickness is required, the material shall be placed in a single layer. When a compacted aggregate layer in excess of 6 inches is required, the material shall be placed in layers of equal thickness. No layer shall be thicker than 6 inches or thinner than 3 inches when compacted. The layers shall be so placed that when compacted they will be true to the grades shown in the plans.

3.5.2 Grade Control

The finished and completed base course shall conform to the lines, grades, and cross sections shown. Underlying material(s) shall be excavated and prepared at sufficient depth for the required base course thickness so that the finished base course and the subsequent surface course will meet the designated grades.

3.5.3 Compaction of Untreated Base Course

Each layer of the Untreated Base Course (UBC) shall be compacted as specified with approved compaction equipment. In all places not accessible to the rollers, the mixture shall be compacted with hand-operated power tampers. Compaction of UBC shall continue until each layer has a degree of compaction that is at least 95 percent of laboratory maximum density through the full depth of the layer. The Contractor shall make such adjustments in compacting or finishing procedures as may be directed to obtain true grades, to minimize segregation and degradation, to reduce or increase water content, and to ensure a satisfactory base course. Any materials that are found to be unsatisfactory shall be removed and replaced with satisfactory material or reworked, as directed, to meet the requirements of this specification.

3.5.4 Thickness

Compacted thickness of the base course shall be as indicated. No individual layer shall be thicker than 6 inches nor be thinner than 3 inches in compacted thickness.

3.5.5 Finishing

The surface of the top layer of base course shall be finished after final compaction by cutting any overbuild to grade and rolling with a steel-wheeled roller. Thin layers of material shall not be added to the top layer of base course to meet grade. If the elevation of the top layer of base course is 1/2 inch or more below grade, then the top layer should be scarified to a depth of at least 3 inches and new material shall be blended in and compacted to bring to grade.

3.5.6 Smoothness of Base Stone for Pavement

The surface of the top layer shall show no deviations in excess of 1/2 inch when tested with a 12 foot straightedge. Measurements shall be taken in successive positions parallel to the centerline of the area to be paved. Measurements shall also be taken perpendicular to the centerline at 50 foot intervals. Deviations exceeding this amount shall be corrected by removing material and replacing with new material, or by reworking existing material and compacting it to meet these specifications.

3.6 INSTALLATION OF RIPRAP

Riprap shall be placed at locations, thicknesses, and sizes indicated on the drawings. At all locations except the Waste Cell at Crescent Junction, riprap shall be placed over a geotextile in accordance with Section 31 05 19 GEOTEXTILE. For the Waste Cell cover slopes, bedding aggregate shall be placed and the riprap installed over the bedding aggregate.

3.7 TRAFFIC

Completed portions of the base course for pavement may be opened to limited traffic, provided there is no marring or distorting of the surface by the traffic. Heavy equipment shall not be permitted except when necessary to construction, and then the area shall be protected against marring or damage to the completed work.

3.8 MAINTENANCE

The base course shall be maintained in a satisfactory condition until the full pavement section is completed and accepted. Maintenance shall include immediate repairs to any defects and shall be repeated as often as necessary to keep the area intact. Any base course that is not paved over prior to the onset of winter, shall be retested to verify that it still complies with the requirements of this specification. Any area of base course that is damaged shall be reworked or replaced as necessary to comply with this specification.

3.9 DISPOSAL OF UNSATISFACTORY MATERIALS

Any unsuitable materials that must be removed shall be disposed of as directed.

-- End of Section --

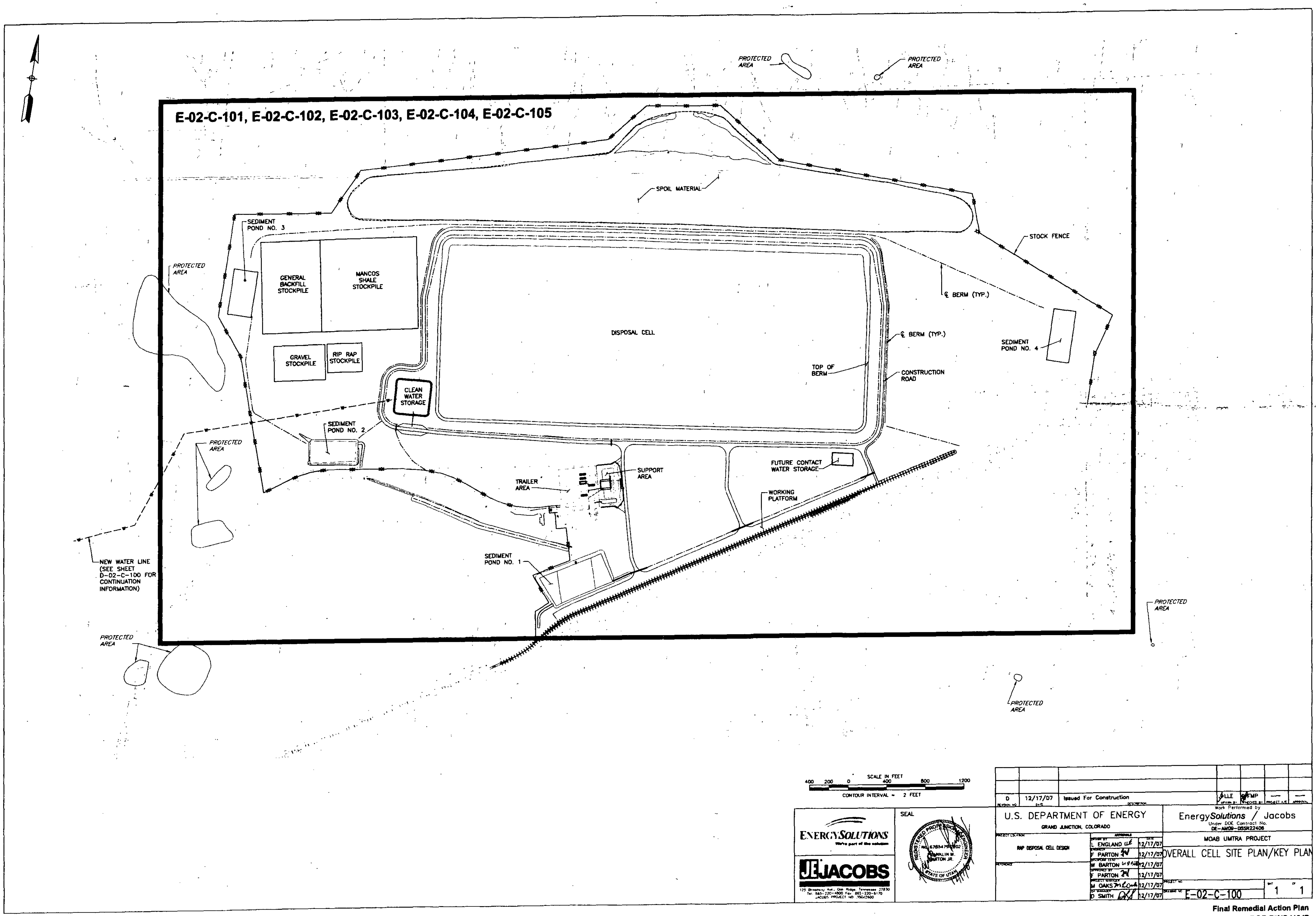
ADDENDUM C

Final Remedial Action Plan
DOE-EM/GJ1547
February 2008

Final Design Drawings

FOR EASY NAVIGATION – CLICK ON SECTION NAME / LINK ABOVE

OR USE BOOKMARKS TAB AT LEFT



E-02-C-101, E-02-C-102, E-02-C-103, E-02-C-104, E-02-C-105
PROTECTED AREA
SPOIL MATERIAL
SEDIMENT POND NO. 3
GENERAL BACKFILL STOCKPILE
MANCOS SHALE STOCKPILE
GRAVEL STOCKPILE
RIP RAP STOCKPILE
CLEAN WATER STORAGE
DISPOSAL CELL
TOP OF BERM
℄ BERM (TYP.)
CONSTRUCTION ROAD
STOCK FENCE
SEDIMENT POND NO. 4
SEDIMENT POND NO. 2
TRAILER AREA
SUPPORT AREA
FUTURE CONTACT WATER STORAGE
WORKING PLATFORM
SEDIMENT POND NO. 1
NEW WATER LINE (SEE SHEET D-02-C-100 FOR CONTINUATION INFORMATION)
SCALE IN FEET
400 200 0 400 800 1200
CONTOUR INTERVAL = 2 FEET
0 12/17/07 Issued For Construction
U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO
Work Performed by
EnergySolutions / Jacobs
Under DOE Contract No. DE-AM09-05SR22406
MOAB UMTRA PROJECT
RAP DISPOSAL CELL DESIGN
L. ENGLAND 12/17/07
F. PARTON 12/17/07
W. BARTON 12/17/07
F. PARTON 12/17/07
M. OAKS 12/17/07
D. SMITH 12/17/07
OVERALL CELL SITE PLAN/KEY PLAN
E-02-C-100
1 1
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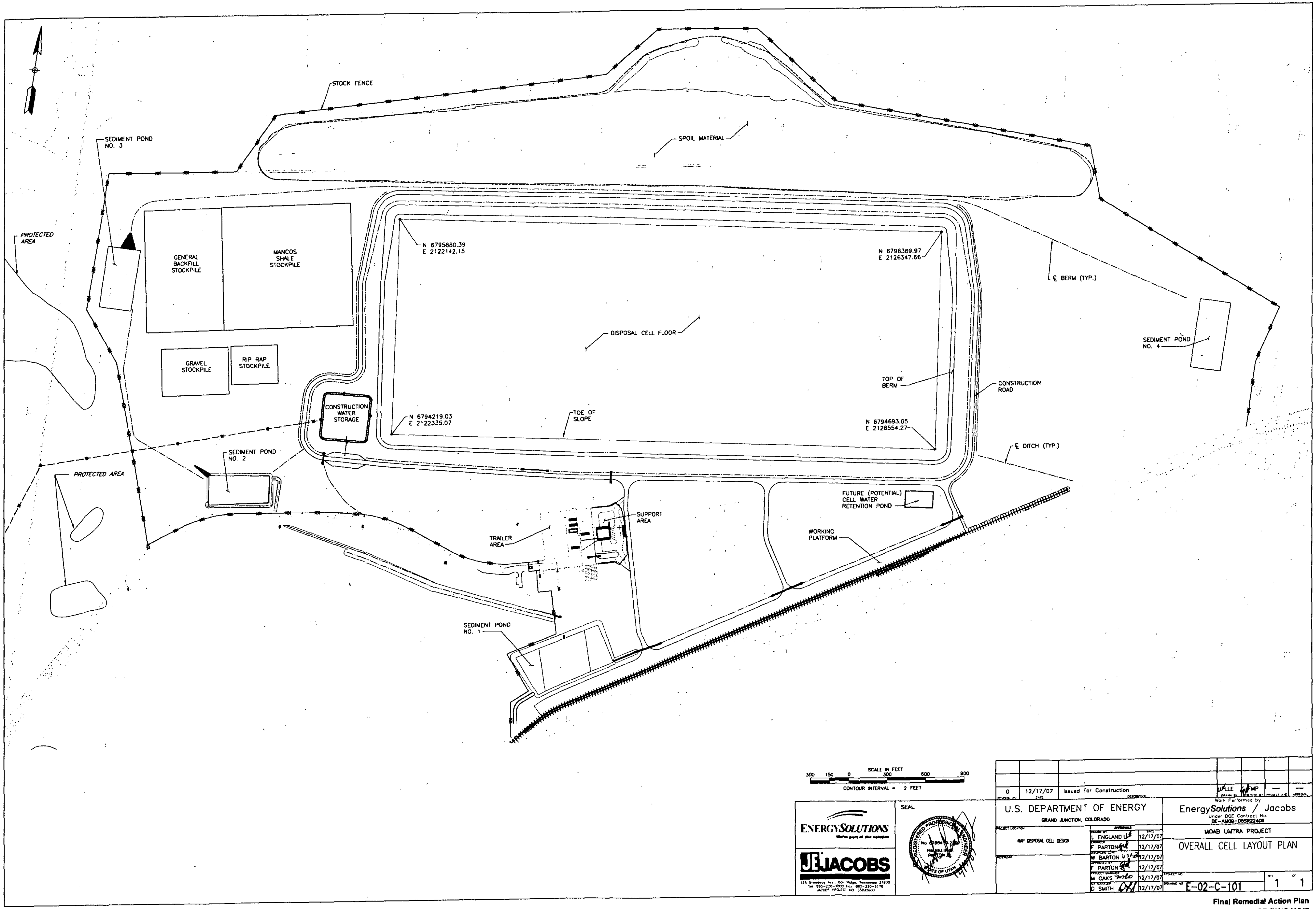
Tel. 865-220-4800 Fax 865-220-6170
JACOBS PROJECT NO. 35OJ2600


STOCK FENCE
SPOIL MATERIAL
SEDIMENT POND NO. 3
PROTECTED AREA
GENERAL BACKFILL STOCKPILE
MANCOS SHALE STOCKPILE
N 6795880.39
E 2122142.15
N 6796369.97
E 2126347.66
℄ BERM (TYP.)
DISPOSAL CELL FLOOR
SEDIMENT POND NO. 4
GRAVEL STOCKPILE
RIP RAP STOCKPILE
TOP OF BERM
CONSTRUCTION ROAD
CONSTRUCTION WATER STORAGE
N 6794219.03
E 2122335.07
TOE OF SLOPE
N 6794693.05
E 2126554.27
℄ DITCH (TYP.)
SEDIMENT POND NO. 2
PROTECTED AREA
FUTURE (POTENTIAL) CELL WATER RETENTION POND
SUPPORT AREA
TRAILER AREA
WORKING PLATFORM
SEDIMENT POND NO. 1
SCALE IN FEET
300 150 0 300 600 900
CONTOUR INTERVAL = 2 FEET
0
12/17/07
Issued For Construction
LLE
FMP
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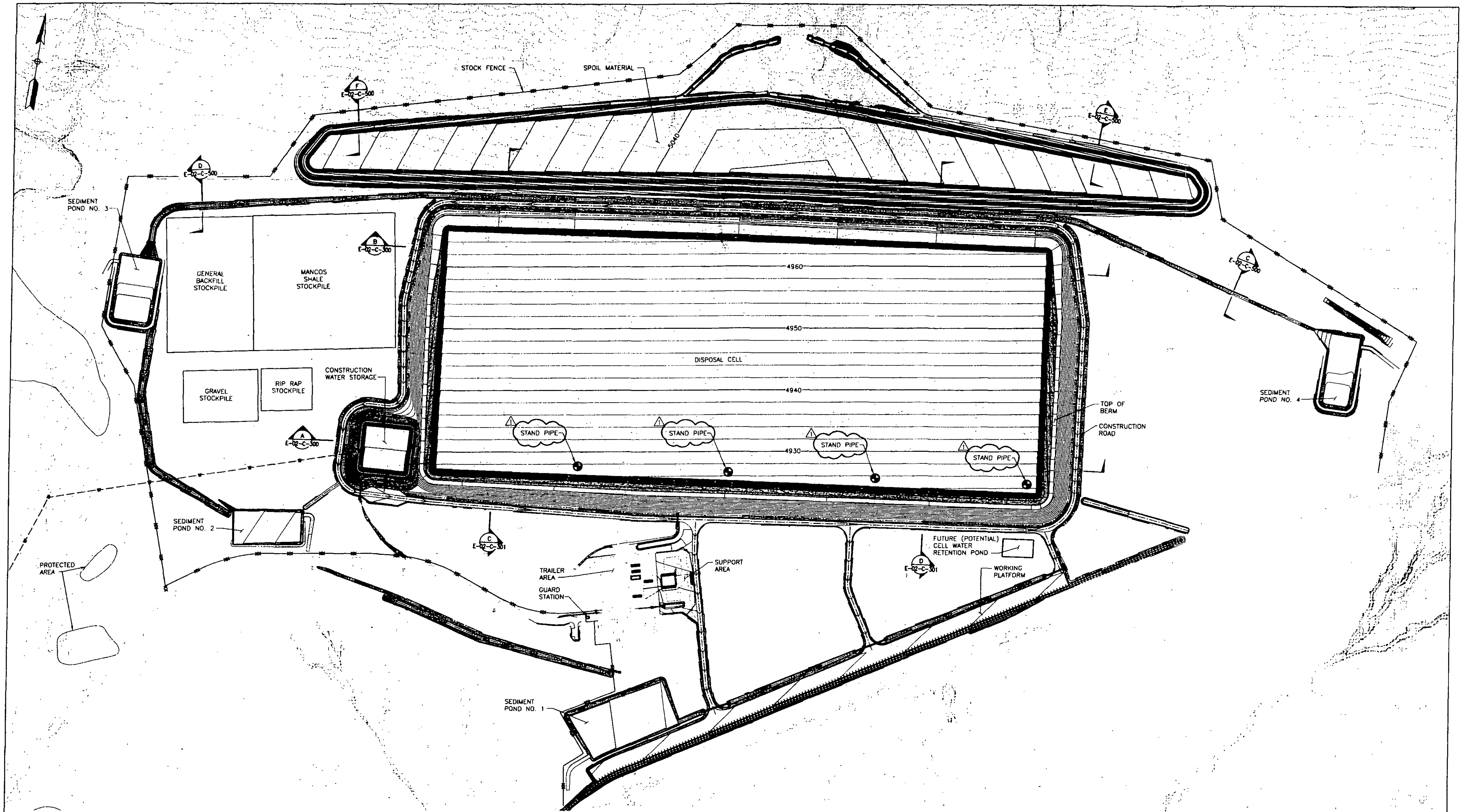
Tel 865-220-4800 Fax 865-220-6170
JACOBS PROJECT NO. 35OJ2600
SEAL
REGISTERED PROFESSIONAL ENGINEER
STATE OF UTAH
U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO
RAP DISPOSAL CELL DESIGN
L ENGLAND 12/17/07
F PARTON 12/17/07
W BARTON 12/17/07
F PARTON 12/17/07
M OAKS 12/17/07
D SMITH 12/17/07
Work Performed by
EnergySolutions / Jacobs
Under DOE Contract No.
DE-AM09-05SR22406
MOAB UMTRA PROJECT
OVERALL CELL LAYOUT PLAN
E-02-C-101
1
1



NOTES:

1. ALL DISTURBED AREAS SHALL BE SEEDED, MULCHED, AND RE-VEGETATED BY OTHERS AT APPROPRIATE TIME.

SCALE IN FEET
300 150 0 300 600 900
CONTOUR INTERVAL = 2 FEET

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JACOBS PROJECT NO: 35G2600

SEAL

REVISION NO	DATE	DESCRIPTION	DRAWN BY	CHECKED BY	PROJECT A/E	APPROVAL
1	02/29/08	Changed monitoring well label to stand pipe	LLE	FMP	GW	MEO
0	12/17/07	Issued For Construction	LLE	FMP		

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GRAND JUNCTION, COLORADO

Work Performed by
EnergySolutions / Jacobs
Under DOE Contract No.
DE-AM09-05SR22406

PROJECT LOCATION: RAP DISPOSAL CELL DESIGN

REFERENCE

APPROVALS	DATE
DRAWN BY: L ENGLAND	12/17/07
ENGINEER: F PARTON	12/17/07
DISCIPLINE LEAD: W BARTON	12/17/07
APPROVED BY: F PARTON	12/17/07
PROJECT MANAGER: M OAKS	12/17/07
QA MANAGER: D SMITH	12/17/07

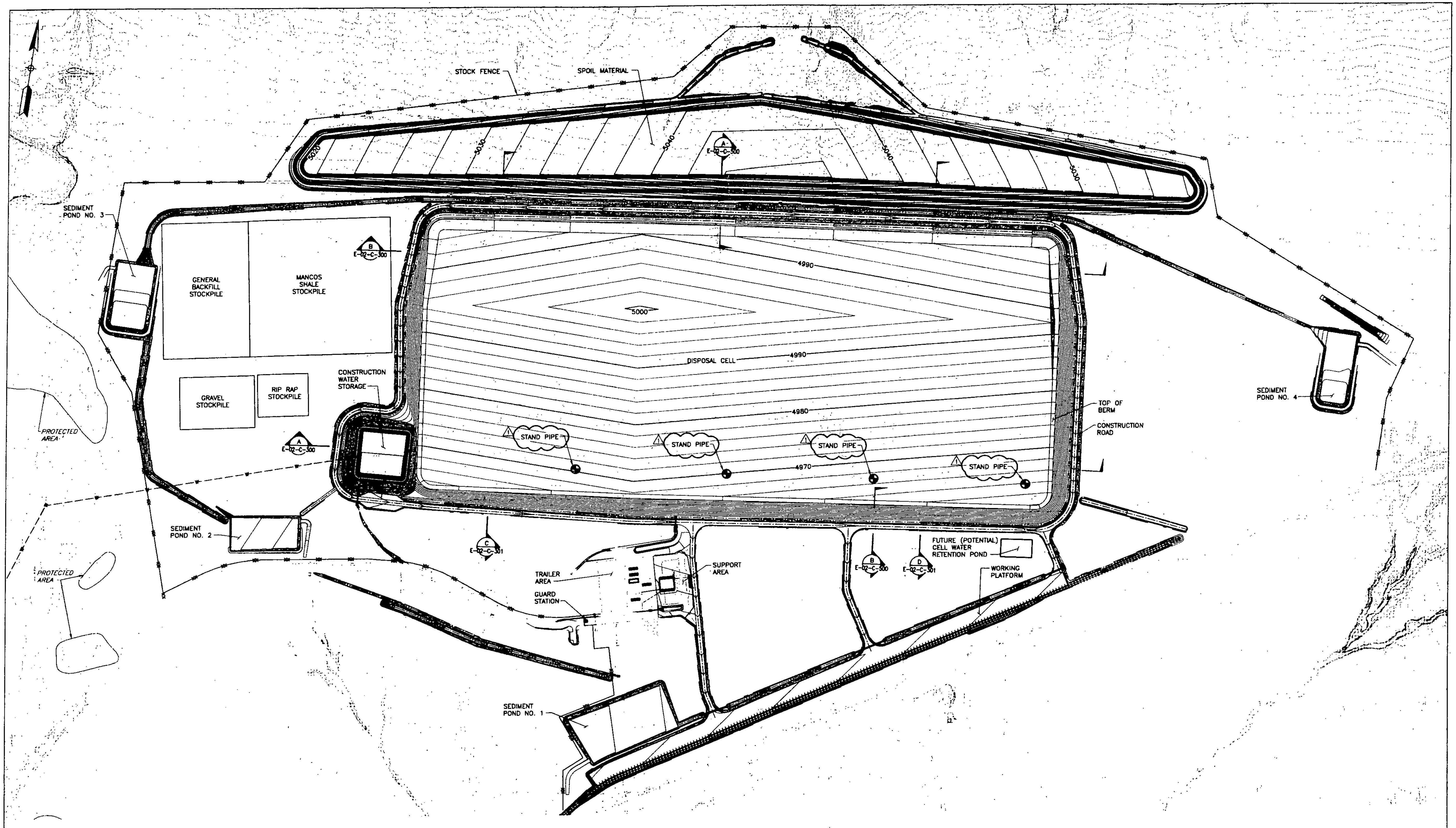
MOAB UMTRA PROJECT

OVERALL CELL GRADING PLAN

PROJECT NO

DRAWING NO E-02-C-102

SHT 1 OF 1



SCALE IN FEET

300 150 0 300 600 900

CONTOUR INTERVAL = 2 FEET

REVISION NO	DATE	DESCRIPTION	DRAWN BY	CHECKED BY	PROJECT A/E	APPROVAL
1	02/29/08	Changed monitoring well label to stand pipe	LLE	FMP		
0	12/17/07	Issued For Construction	LLE	FMP		

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Tel 865-220-4800 Fax 865-220-6170
JACOBS PROJECT NO 35OJ2800

SEAL
REGISTERED PROFESSIONAL ENGINEER
No. 6785479 2202
FRANKLIN M PARTON JR.
STATE OF UTAH

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO

Work Performed by
EnergySolutions / Jacobs
Under DOE Contract No DE-AM09-05SR22406

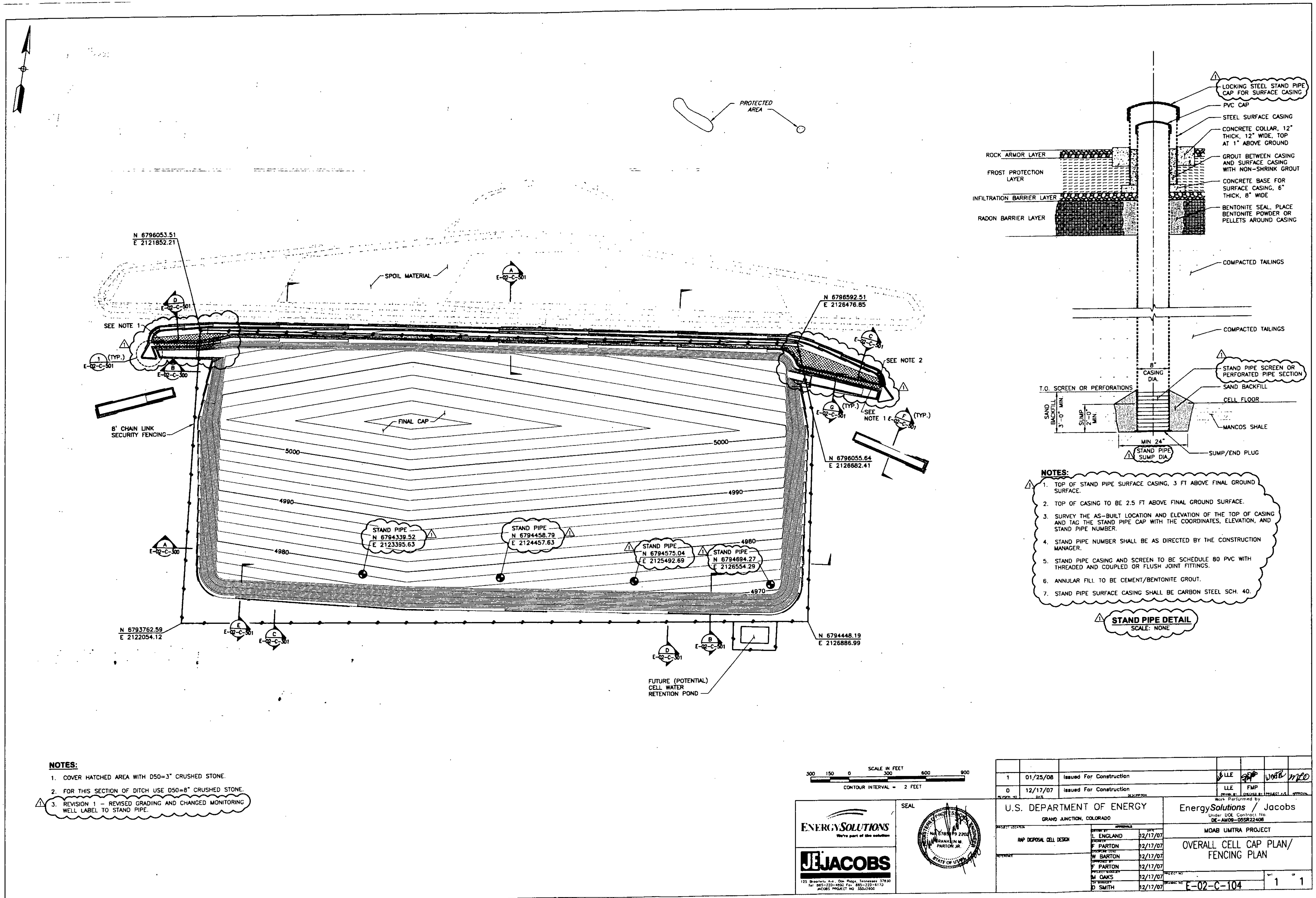
PROJECT LOCATION: RAP DISPOSAL CELL DESIGN

APPROVALS	DATE
L ENGLAND	12/17/07
F PARTON	12/17/07
W BARTON	12/17/07
F PARTON	12/17/07
M OAKS	12/17/07
D SMITH	12/17/07

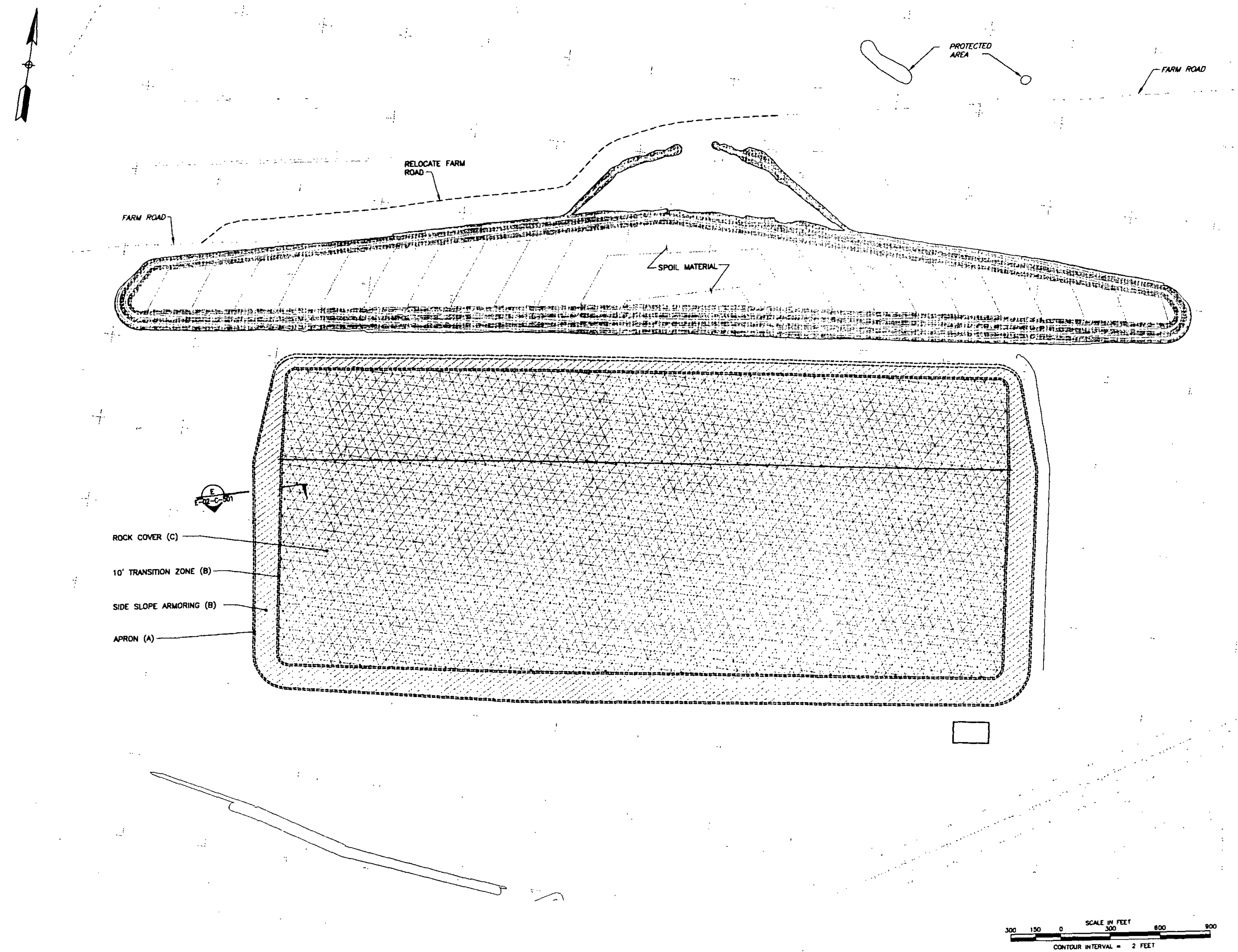
MOAB UMTRA PROJECT

OVERALL CELL
TOP OF WASTE PLAN

DRAWING NO E-02-C-103 SHT 1 OF 1



PROTECTED AREA
SPOIL MATERIAL
FINAL CAP
5000
4990
4980
4970
SEE NOTE 1
SEE NOTE 2
N 6796053.51
E 2121852.21
N 6796592.51
E 2126476.85
N 6796055.64
E 2126682.41
N 6793762.59
E 2122054.12
N 6794448.19
E 2126886.99
8' CHAIN LINK SECURITY FENCING
STAND PIPE
N 6794339.52
E 2123395.63
STAND PIPE
N 6794458.79
E 2124457.63
STAND PIPE
N 6794575.04
E 2125492.69
STAND PIPE
N 6794694.27
E 2126554.29
FUTURE (POTENTIAL) CELL WATER RETENTION POND
LOCKING STEEL STAND PIPE CAP FOR SURFACE CASING
PVC CAP
STEEL SURFACE CASING
CONCRETE COLLAR, 12" THICK, 12" WIDE, TOP AT 1" ABOVE GROUND
GROUT BETWEEN CASING AND SURFACE CASING WITH NON-SHRINK GROUT
CONCRETE BASE FOR SURFACE CASING, 6" THICK, 8" WIDE
BENTONITE SEAL, PLACE BENTONITE POWDER OR PELLETS AROUND CASING
ROCK ARMOR LAYER
FROST PROTECTION LAYER
INFILTRATION BARRIER LAYER
RADON BARRIER LAYER
COMPACTED TAILINGS
COMPACTED TAILINGS
STAND PIPE SCREEN OR PERFORATED PIPE SECTION
SAND BACKFILL
CELL FLOOR
MANCOS SHALE
SUMP/END PLUG
8" CASING DIA.
T.O. SCREEN OR PERFORATIONS
SAND BACKFILL 3'-0" MIN.
SUMP 2'-0" MIN.
MIN 24"
STAND PIPE SUMP DIA.
NOTES:
1. TOP OF STAND PIPE SURFACE CASING, 3 FT ABOVE FINAL GROUND SURFACE.
2. TOP OF CASING TO BE 2.5 FT ABOVE FINAL GROUND SURFACE.
3. SURVEY THE AS-BUILT LOCATION AND ELEVATION OF THE TOP OF CASING AND TAG THE STAND PIPE CAP WITH THE COORDINATES, ELEVATION, AND STAND PIPE NUMBER.
4. STAND PIPE NUMBER SHALL BE AS DIRECTED BY THE CONSTRUCTION MANAGER.
5. STAND PIPE CASING AND SCREEN TO BE SCHEDULE 80 PVC WITH THREADED AND COUPLED OR FLUSH JOINT FITTINGS.
6. ANNULAR FILL TO BE CEMENT/BENTONITE GROUT.
7. STAND PIPE SURFACE CASING SHALL BE CARBON STEEL SCH. 40.
STAND PIPE DETAIL
SCALE: NONE
NOTES:
1. COVER HATCHED AREA WITH D50=3" CRUSHED STONE.
2. FOR THIS SECTION OF DITCH USE D50=8" CRUSHED STONE.
3. REVISION 1 - REVISED GRADING AND CHANGED MONITORING WELL LABEL TO STAND PIPE.
SCALE IN FEET
300 150 0 300 600 900
CONTOUR INTERVAL = 2 FEET
1 01/25/08 Issued For Construction
0 12/17/07 Issued For Construction
U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO
EnergySolutions / Jacobs
RAP DISPOSAL CELL DESIGN
L ENGLAND 12/17/07
F PARTON 12/17/07
W BARTON 12/17/07
F PARTON 12/17/07
M OAKS 12/17/07
D SMITH 12/17/07
MOAB UMTRA PROJECT
OVERALL CELL CAP PLAN/ FENCING PLAN
E-02-C-104
1 1



REVISION NO	DATE	DESCRIPTION	DRAWN BY	CHECKED BY	PROJECT A/E	APPROVAL
0	12/17/07	Issued For Construction	LLE	FMP	—	—

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JACOBS PROJECT NO 35OJ2600

SEAL

REGISTERED PROFESSIONAL ENGINEER
No. 6785479-2202
FRANKLIN M. PARTON JR.
STATE OF UTAH

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO

PROJECT LOCATION
RAP DISPOSAL CELL DESIGN

REFERENCE

APPROVALS	DATE
DRAWN BY L. ENGLAND	12/17/07
CHECKED F. PARTON	12/17/07
DISCIPLINE LEAD W. BARTON	12/17/07
APPROVED BY F. PARTON	12/17/07
PROJECT MANAGER M. OAKS	12/17/07
QA MANAGER D. SMITH	12/17/07

Work Performed by
EnergySolutions / Jacobs
Under DOE Contract No
DE-AM09-05SR22406

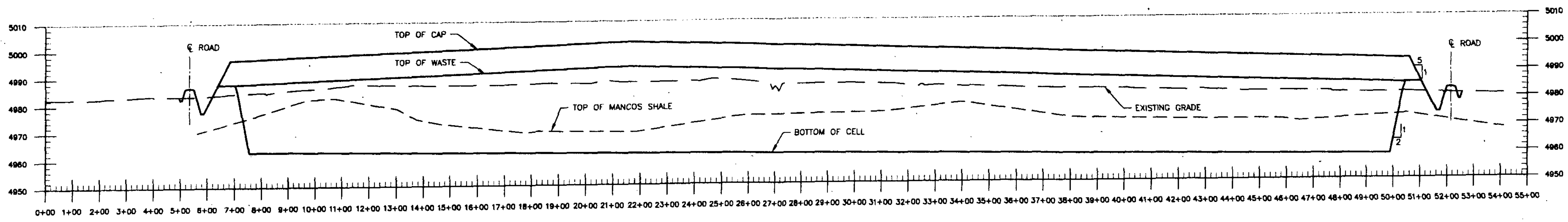
MOAB UMTRA PROJECT

ROCK COVER PLAN

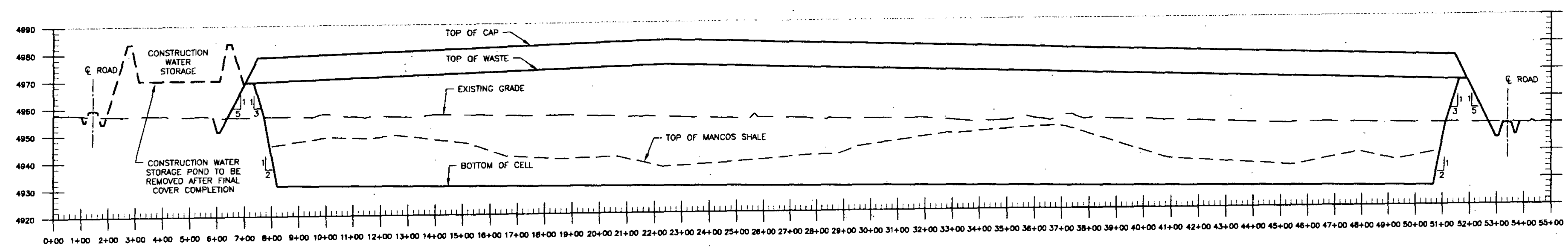
PROJECT NO

DRAWING NO E-02-C-105

SHT 1 OF 1



B SECTION
SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=20'
E-02-C-102
E-02-C-103
E-02-C-104



A SECTION
SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=20'
E-02-C-102
E-02-C-103
E-02-C-104

SCALE IN FEET: 200 100 0 200 400 600 — HORIZONTAL
SCALE IN FEET: 20 10 0 20 40 60 — VERTICAL

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GRAND JUNCTION, COLORADO

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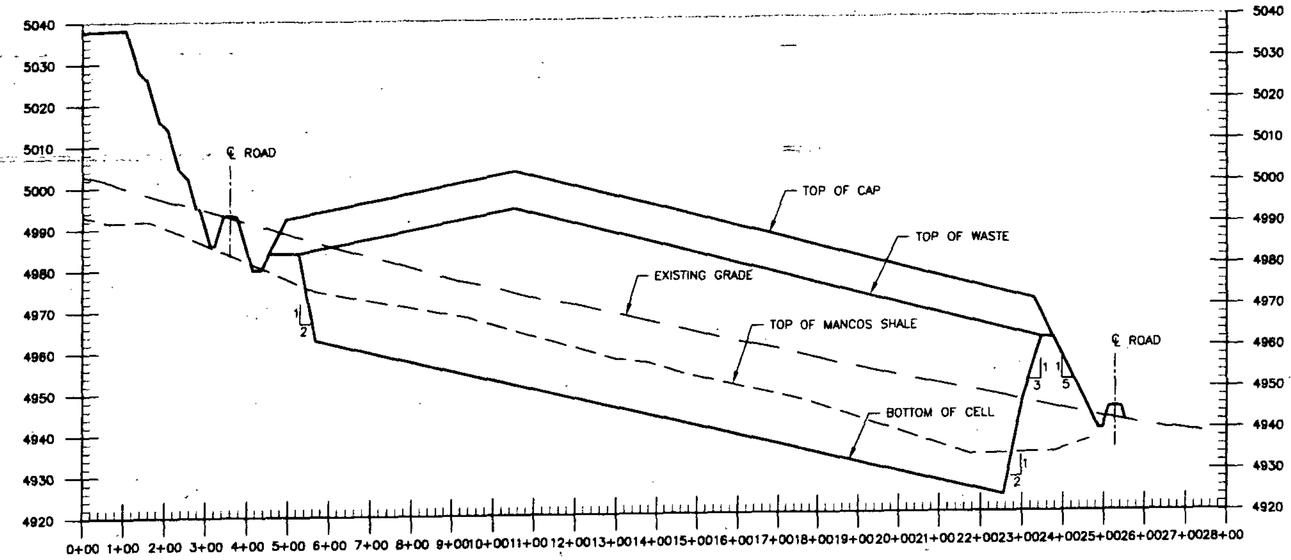
Under DOE Contract No DE-AM09-05SR22406

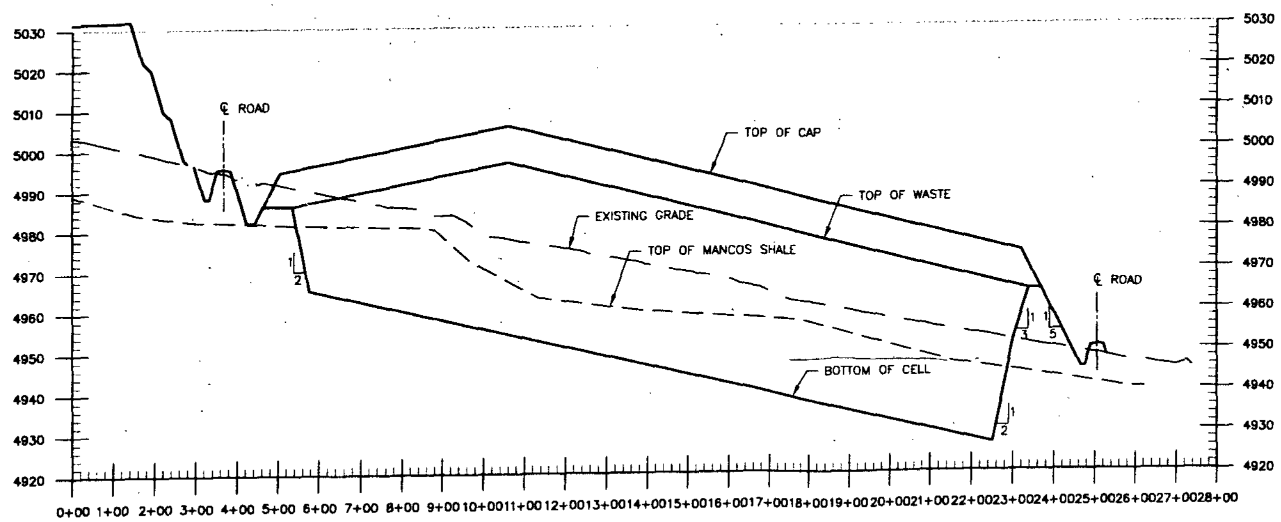
RAP DISPOSAL CELL DESIGN

L ENGLAND 12/17/07
F PARTON 12/17/07
W BARTON 12/17/07
F PARTON 12/17/07
M OAKS 12/17/07
D SMITH 12/17/07

MOAB UMTRA PROJECT
DISPOSAL CELL CROSS SECTIONS
E-02-C-300
1 1



D SECTION
E-02-C-102
E-02-C-103
E-02-C-104
SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=20'



C SECTION
E-02-C-102
E-02-C-103
E-02-C-104
SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=20'

SCALE IN FEET: 200 100 0 200 400 600 — HORIZONTAL

SCALE IN FEET: 20 10 0 20 40 60 — VERTICAL

REVISION NO	DATE	DESCRIPTION	DRAWN BY	CHECKED BY	PROJECT A/E	APPROVAL
0	12/17/07	Issued For Construction	LLE	FMP	—	—

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GRAND JUNCTION, COLORADO

Work Performed by EnergySolutions / Jacobs
Under DOE Contract No DE-AM09-05SR22406

PROJECT LOCATION: RAP. DISPOSAL CELL DESIGN

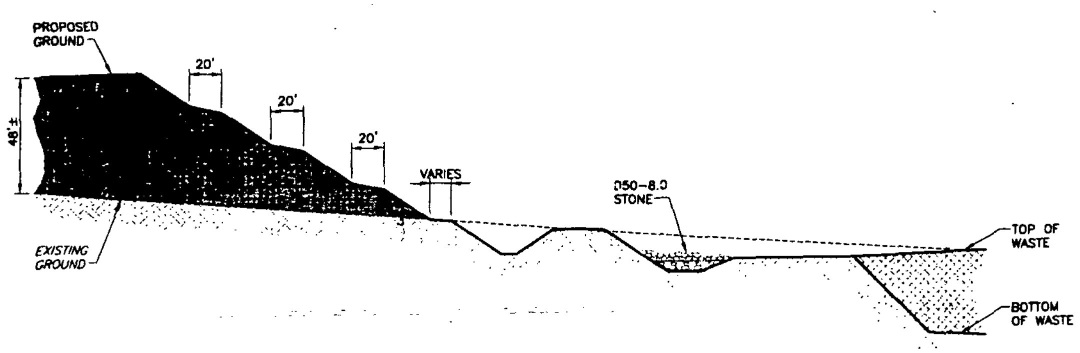
REFERENCE

APPROVALS	DATE
DRAWN BY L ENGLAND	12/17/07
ENGINEER F PARTON	12/17/07
DISCIPLINE LEAD W BARTON	12/17/07
APPROVED BY F PARTON	12/17/07
PROJECT MANAGER M OAKS	12/17/07
QA MANAGER D SMITH	12/17/07

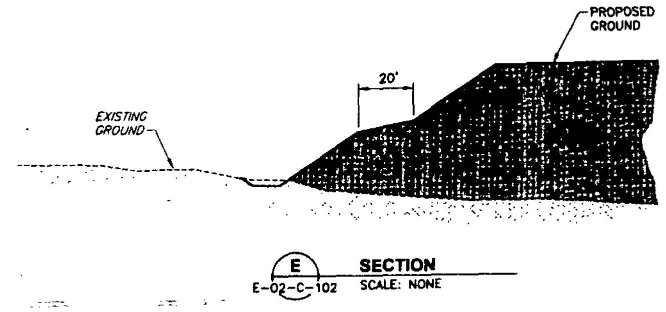
MOAB UMTRA PROJECT

DISPOSAL CELL CROSS SECTIONS

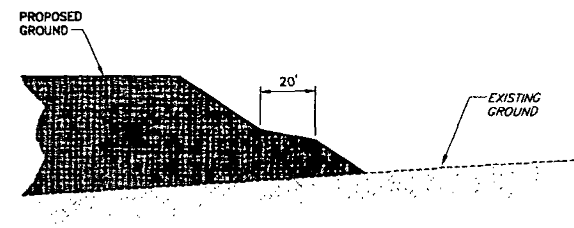
DRAWING NO E-02-C-301 SHT 1 OF 1



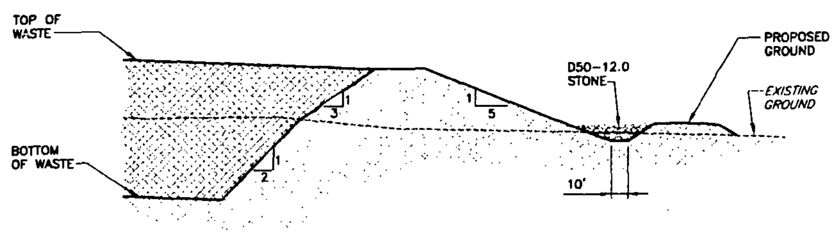
A SECTION
E-02-C-102 SCALE: NONE



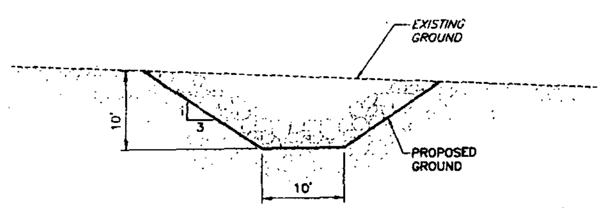
E SECTION
E-02-C-102 SCALE: NONE



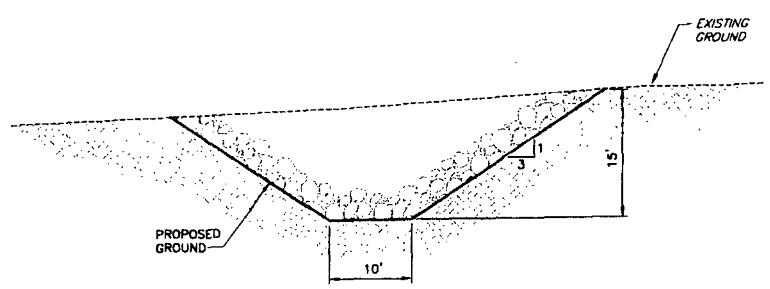
F SECTION
E-02-C-102 SCALE: NONE



B SECTION
E-02-C-103 SCALE: NONE



C SECTION
E-02-C-102 SCALE: NONE



D SECTION
E-02-C-102 SCALE: NONE

0	12/17/07	Issued For Construction	LLE	MP	—	—
REVISION NO	DATE	DESCRIPTION	DRAWN BY	CHECKED BY	PROJECT A/E	APPROVAL

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Tel 865-220-4800 Fax 865-220-8170
JACOBS PROJECT NO 35DJ2600

SEAL

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO

PROJECT LOCATION: RAP DISPOSAL CELL DESIGN

REFERENCE

APPROVALS	DATE
DRAWN BY: L ENGLAND	12/17/07
ENGINEER: F PARTON	12/17/07
DISCIPLINE LEAD: W BARTON	12/17/07
APPROVED BY: F PARTON	12/17/07
PROJECT MANAGER: M OAKS	12/17/07
DOE MANAGER: D SMITH	12/17/07

Work Performed by
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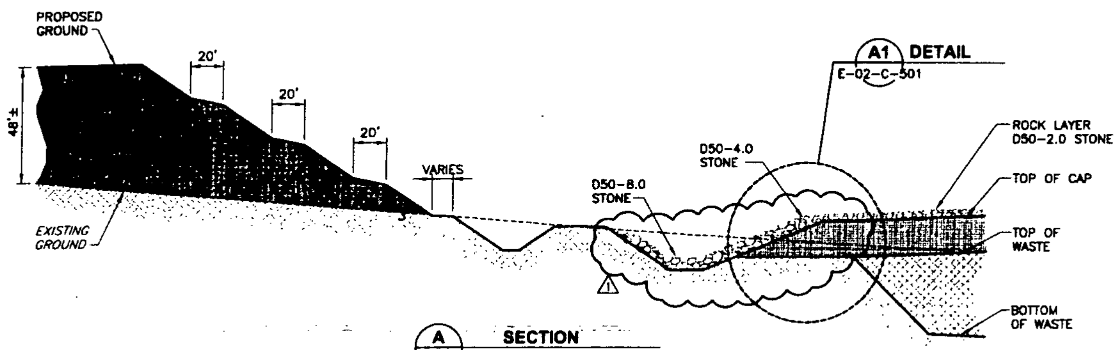
Under DOE Contract No.
DE-AM09-05SR22406

MOAB UMTRA PROJECT

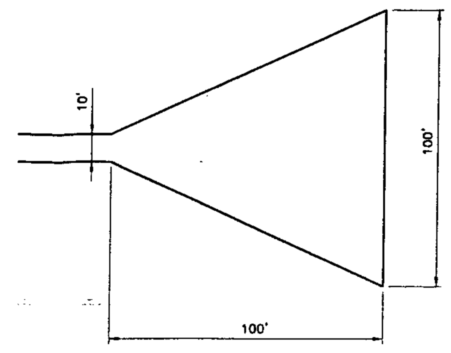
DETAILS - 1

PROJECT NO

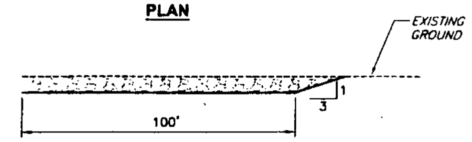
DRAWING NO E-02-C-500 SHT 1 OF 1



A SECTION
E-02-C-104 SCALE: NONE

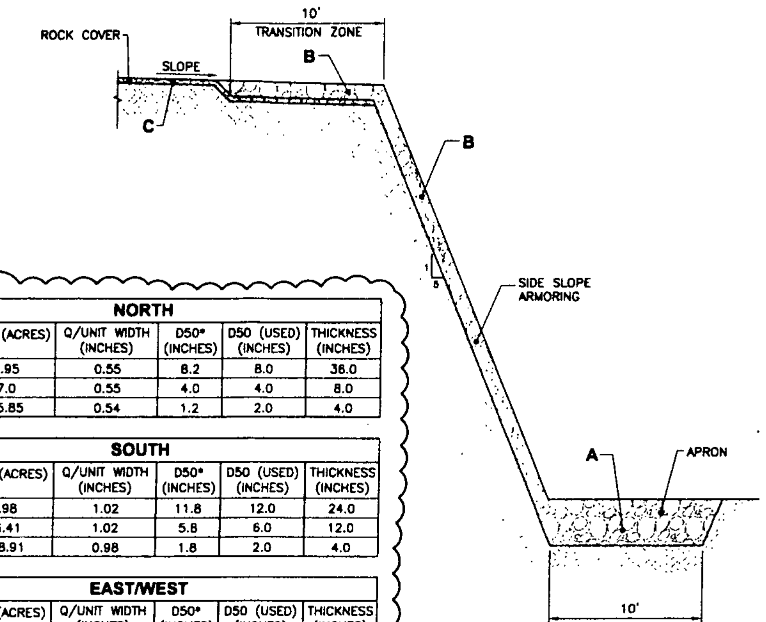


PLAN



SECTION- LEVEL SPREADER

1 DETAIL
E-02-C-104 SCALE: NONE



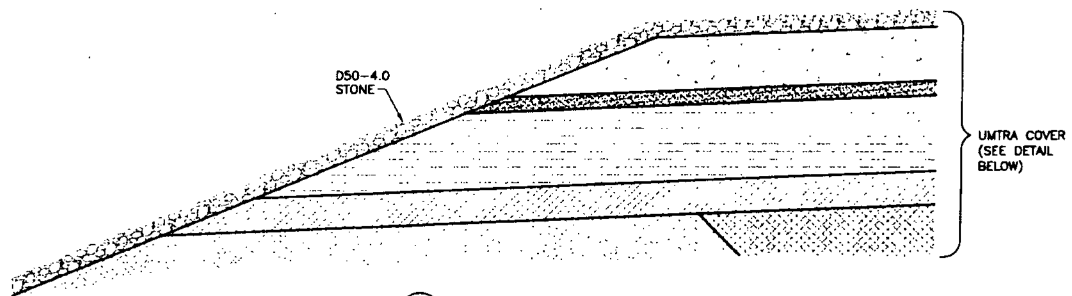
NORTH	AREA (ACRES)	Q/UNIT WIDTH (INCHES)	D50* (INCHES)	D50 (USED) (INCHES)	THICKNESS (INCHES)
A	1.95	0.55	8.2	8.0	36.0
B	7.0	0.55	4.0	4.0	8.0
C	55.85	0.54	1.2	2.0	4.0

SOUTH	AREA (ACRES)	Q/UNIT WIDTH (INCHES)	D50* (INCHES)	D50 (USED) (INCHES)	THICKNESS (INCHES)
A	0.98	1.02	11.8	12.0	24.0
B	16.41	1.02	5.8	6.0	12.0
C	128.91	0.98	1.8	2.0	4.0

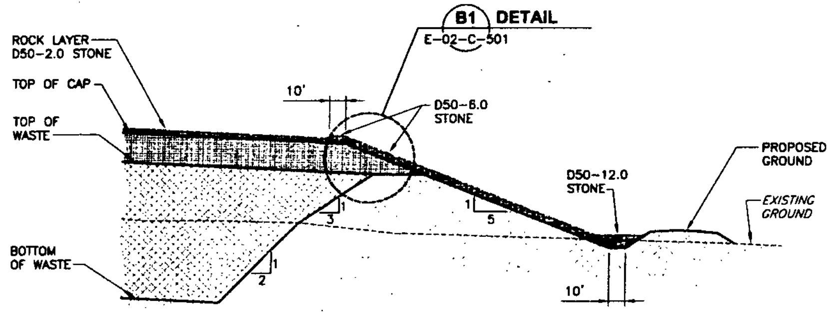
EAST/WEST	AREA (ACRES)	Q/UNIT WIDTH (INCHES)	D50* (INCHES)	D50 (USED) (INCHES)	THICKNESS (INCHES)
A	1.08	0.2	4.7	6.0	18.0
B	13.63	0.2	2.3	4.0	8.0
C	NA	NA	NA	NA	NA

*CALCULATED VALUE

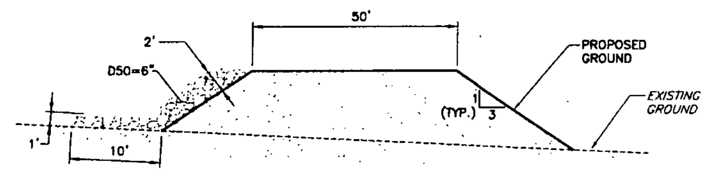
E SECTION
E-02-C-104 SCALE: NONE



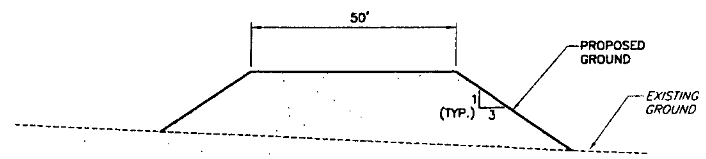
A1 DETAIL
E-02-C-501 SCALE: NONE



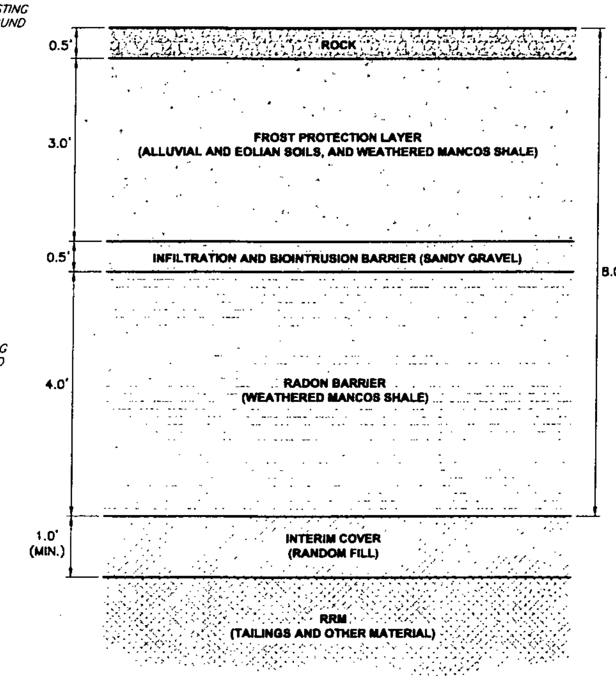
B SECTION
E-02-C-104 SCALE: NONE



F SECTION
E-02-C-104 SCALE: NONE



G SECTION
E-02-C-104 SCALE: NONE



UMTRA COVER DESIGN

Final Cover

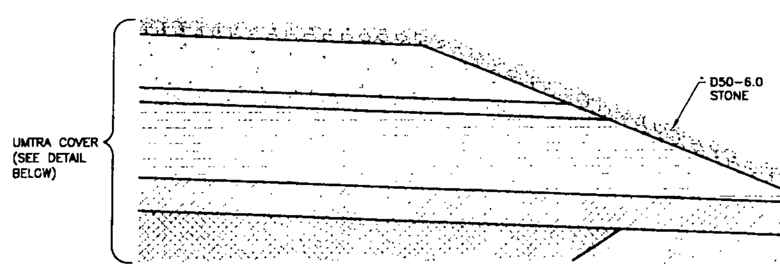
	Volume (CY)	Volume (MCY)
Waste	11200000	11.2
Interim Cover	298144	0 298
Radon Barrier	1192576	1.193
Infiltration Barrier	149072	0 149
Frost Protection Layer	894432	0 894

	Vol (CF) D_{50} 12 in	Vol (CF) D_{50} 8 in	Vol (CF) D_{50} 6 in	Vol (CF) D_{50} 4 in	Vol (CF) D_{50} 2 in
Total Vol A	130680	169884	71874		
Total Vol B			714384	598224	
Total Vol C					2683296 0
Total (CF)	130680	169884	786258	598224	2683296
Total (ton)	6077	7900	36561	27817	156973

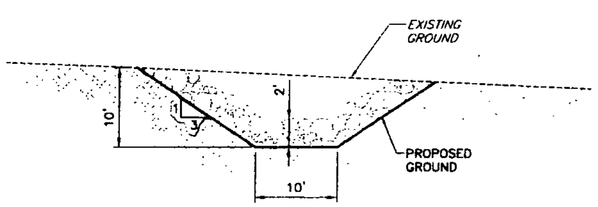
Each Additional 50' Expansion West

	Volume (CY)
Waste	123044
Interim Cover	3406
Radon Barrier	13822
Infiltration Barrier	1703
Frost Protection Layer	10217

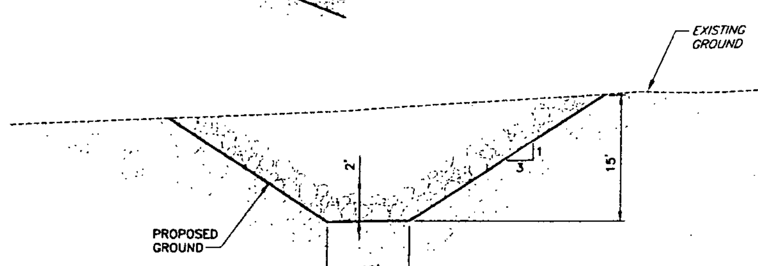
	Vol (CF) D_{50} 12 in	Vol (CF) D_{50} 8 in	Vol (CF) D_{50} 6 in	Vol (CF) D_{50} 4 in	Vol (CF) D_{50} 2 in
Total Vol A	189	296			
Total Vol B			298	63	
Total Vol C					852
Total (CF)	189	296	298	63	852
Total (ton)	9	14	14	3	50



B1 DETAIL
E-02-C-501 SCALE: NONE



C SECTION
E-02-C-104 SCALE: NONE



D SECTION
E-02-C-104 SCALE: NONE

NOTE:

1. REVISION 1 – ADDED UNITS OF MEASUREMENT TO ROCK COVER COLUMNS AND REVISED SECTION A.

1	02/29/08	Issued For Construction	LLE	FMP
0	12/17/07	Issued For Construction	LLE	FMP

ENERGYSOLUTIONS
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JACOBS

SEAL

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO

RAP DISPOSAL CELL DESIGN

L ENGLAND	12/17/07
F PARTON	12/17/07
W BARTON	12/17/07
F PARTON	12/17/07
M OAKS	12/17/07
D SMITH	12/17/07

Work Performed by
EnergySolutions / Jacobs
Under DOE Contract No. DE-AM09-05SR22406

MOAB UMTRA PROJECT

DETAILS - 2

E-02-C-501 1 1

Addendum D

Final Remedial Action Plan
DOE-EM/GJ1547
February 2008

Final Design Calculations

Number	Title	Pages
C-02	Disposal Cell Erosion Protection	57
C-03	Wedge Longevity	73
C-04	Area Between Cell and Wedge	54
C-05	Radon Barrier Evaluation	35
C-06	Drainage During First Phase of Construction	12
C-10	Slope Stability of Crescent Junction Disposal Cell	13
C-11	Settlement Analysis of Uranium Mine Tailings at Crescent Junction, UT	12
C-12	Liquefaction Analysis of Uranium Mine Tailings Repository at Crescent Junction, UT	22
C-13	Frost Penetration Depth at Crescent Junction Disposal Site	32
C-15	Analysis for Cover Cracking of the Crescent Junction Disposal Cell	13

FOR EASY NAVIGATION – CLICK ON SECTION NAME / LINK ABOVE

OR USE BOOKMARKS TAB AT LEFT

JACOBS ***Calculation Cover Sheet*** **(Ref. FOWI 116 Design Calculations)**	Calculation No: C-02	Page 1 of 17 – Plus Appendices 40 Pgs
	Rev. No.: 0	Revision Date:
	Previous Revision Date:	Current Revision Date:1/09/08
Issuing Department: *Federal Operations Design Engineering*	Supersedes:	
Client: Energy solutions Project Title: Moab UMTRA Project Number: 35DJ2600 System:	Engineering Discipline: Civil	
Calculation Title: Disposal cell Erosion Protection		

Purpose:

Determine the rock protection required to protect the cover of the Crescent Junction disposal cell from erosion due to precipitation directly on the cell to meet the specifications of the *Code of Federal Regulations* (CFR) (40 CFR part 192).

Prepared by: Bob Yager *Robert E. Yager* Date: 1/09/08

Checked by: Bill Barton *Bill Barton* Date: 1/25/08

Engineering Managers Approval: *Bill Barton* Date: 1/25/08

Revision History:

Pages Affected By Revision	Revised/Added/Deleted	Description of Revision
All		

Description of Calculation:

- Determine the peak unit discharge from the Probable Maximum Precipitation (PMP) using methods given in the UMTRA TAD (DOE 1989).
- Calculate the required rock size (D50) on the top slope of the disposal cell using the Safety Factor method (Nelson et al. 1986).
- Calculate the required rock size (D50) on the side slopes of the disposal cell using Abt and Johnson method (Abt and Johnson 1991).
- Calculate the required rock size (D50) for the toe apron to accommodate flow transitioning from cell slope to native ground using the method proposed by Abt et al. (1998).
- Evaluate the scour potential of flow from the toe apron using methods in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (1983).
- Evaluate the need for a bedding layer between cover soils and erosion protection material by estimating interstitial pore velocities using the method proposed by Abt and Johnson (1991).

Assumptions:

- The PMP precipitation event is applicable for long-term erosional stability analyses.
- The 1-hour PMP event is estimated to be 8.2 inches, ("Site Drainage—Hydrology Parameters" calculation, Draft RAP Attachment 1, Appendix E).
- Rock available for erosion protection will be angular, have a specific gravity of 2.65, and will meet Nuclear Regulatory Commission (NRC) durability requirements.
- For the PMP precipitation event, all the rainfall runs off during the peak rainfall intensity (C=1.0 for the Rational Method).

Design Inputs:

Software:

Title	Developer	Versions	Revision Level
EXCEL	Microsoft	2002	

Calculation Section:

See Following text

Conclusions/Recommendations:

See following text.

Reference:

See following text.

DESCRIPTION OF CALCULATION:

Determine the rock protection required to protect the cover of the disposal cell from erosion due to precipitation directly on the cell to meet the specifications of the *Code of Federal Regulations* (CFR) (40 CFR part 192).

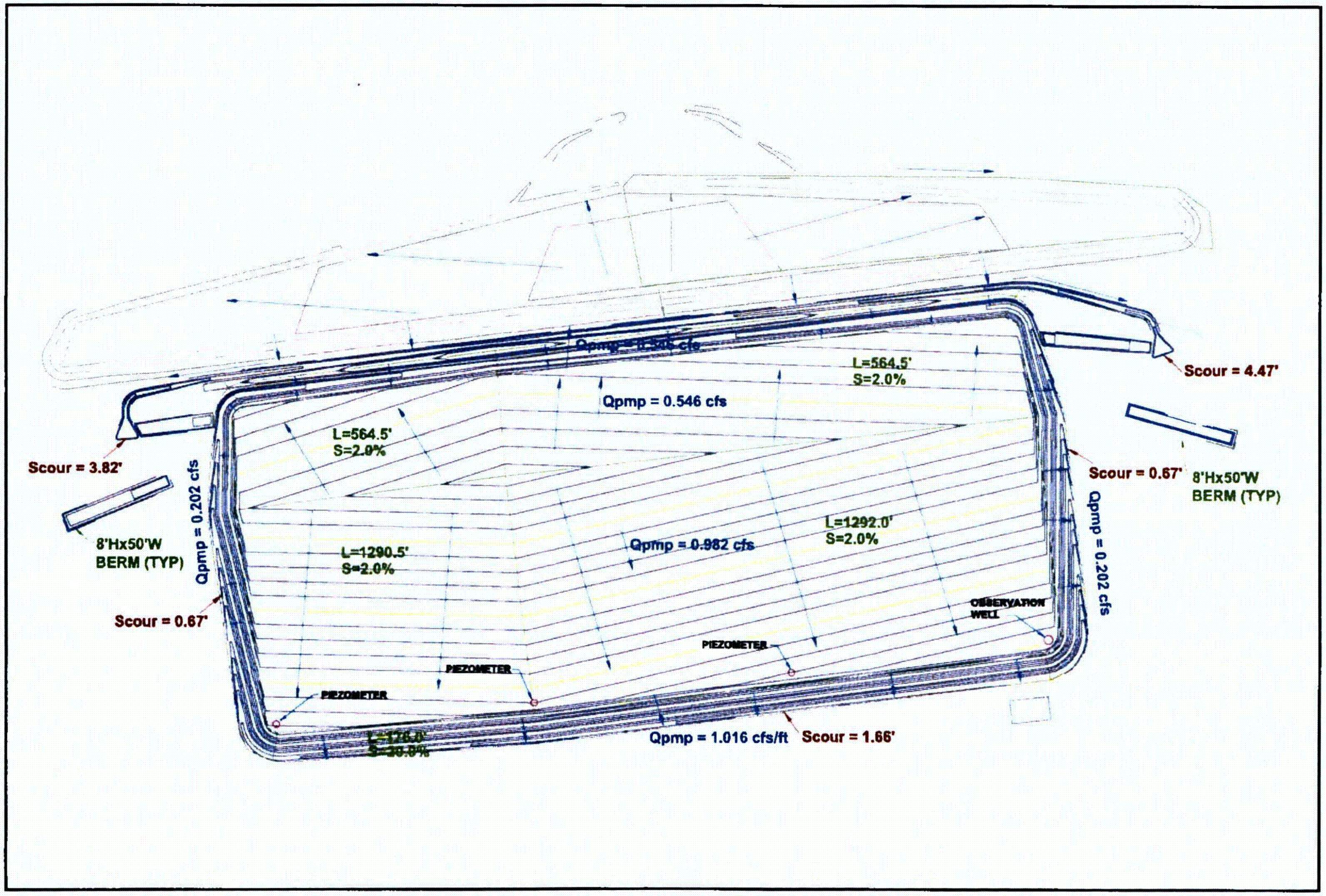
METHOD OF SOLUTION:

- Determine the peak unit discharge from the Probable Maximum Precipitation (PMP) using methods given in the UMTRA TAD (DOE 1989).
- Calculate the required rock size (D50) on the top slope of the disposal cell using the Safety Factor method (Nelson et al. 1986).
- Calculate the required rock size (D50) on the side slopes of the disposal cell using Abt and Johnson method (Abt and Johnson 1991).
- Calculate the required rock size (D50) for the toe apron to accommodate flow transitioning from cell slope to native ground using the method proposed by Abt et al. (1998).
- Evaluate the scour potential of flow from the toe apron using methods in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (1983).
- Evaluate the need for a bedding layer between cover soils and erosion protection material by estimating interstitial pore velocities using the method proposed by Abt and Johnson (1991).

ASSUMPTIONS:

- The PMP precipitation event is applicable for long-term erosional stability analyses.
- The 1-hour PMP event is estimated to be 8.2 inches, ("Site Drainage—Hydrology Parameters" calculation, Draft RAP Attachment 1, Appendix E).
- Rock available for erosion protection will be angular, have a specific gravity of 2.65, and will meet Nuclear Regulatory Commission (NRC) durability requirements.
- For the PMP precipitation event, all the rainfall runs off during the peak rainfall intensity (C=1.0 for the Rational Method).

Figure 1. Disposal Cell Layout



CALCULATION SECTION:

SPREADSHEETS WHERE CALCULATIONS WERE PERFORMED INCLUDED IN THIS CALCULATION PACKAGE ARE. CELLRIPRAP.XLS AND APRONSCOUR.XLS.

Drainage Area Characteristics

The layout of the disposal cell is shown in Figure 1. A cross section from the top to the apron on the south side is shown in Figure 2. The cell will have a 2 percent top slope, 5:1 (horizontal:vertical) side slopes, and a total footprint area of 251 acres.

Six drainage areas were delineated on the cover of the disposal cell, as shown in Figure 1. The area and flow length of these drainage areas were calculated using computer-aided design (CAD) tools.

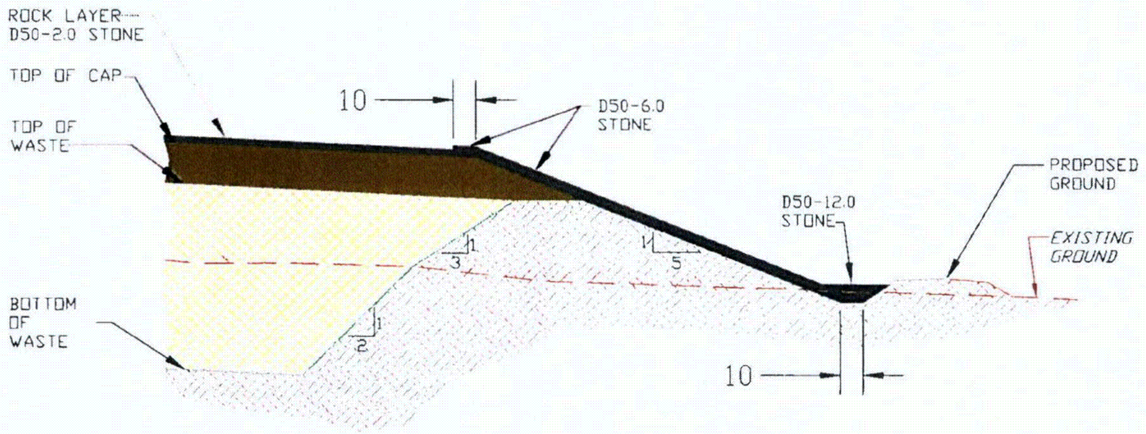


Figure 2 Cross section of the south slope of the waste cell.

Peak flows occurring within each drainage area are calculated using a rainfall duration equivalent to the time of concentration for each drainage basin. The time of concentration is a characteristic of the geometry and slopes of the drainage areas, and is computed by three different methods, with the average of the three methods used to calculate peak discharges. The three methods used to calculate the time of concentration are described below. The mean of the three times calculated was used as the time of concentration in runoff calculations.

1) The Kirpich equation as presented in NUREG/CR-4620 (Nelson et al. 1986):

$$T_c = 0.0078 \frac{L^{0.77}}{S^{0.385}}$$

where:

T_c = time of concentration (minutes),

L = slope length (feet [ft]), and
S = slope (ft/ft).

2) The Soil Conservation Service (SCS) Triangular Hydrograph Theory, as presented in NUREG/CR-4620 (Nelson et al. 1986):

$$T_c = \left(\frac{11.9L^3}{H}\right)^{0.385}$$

where:

T_c = time of concentration (hours),
L = slope length (miles), and
H = slope height (ft).

3) The Brant and Oberman equation as presented in the Uranium Mill Tailings Remedial Action Project (UMTRA) Technical Approach Document (TAD) (DOE 1989):

$$T_c = C\left(\frac{L}{Si^2}\right)^{\frac{1}{3}}$$

where:

T_c = time of concentration (minutes),
C = coefficient = 1.0 for bare earth,
S = slope (ft/ ft), and
i = one-hour rainfall intensity (inches/hour).

As specified in UMTRA TAD (DOE 1989), T_c is limited to a minimum of 2.5 minutes. Because precipitation falling on the top of the cover flows to the north and south slopes, the time of concentration for each of these side slopes is equivalent to the time of concentration for precipitation on the top slope plus the time of concentration for precipitation on the side slope. The characteristics of the drainage areas on the disposal cell are summarized in Table 1. Where there is some variation of slope length within an area, the maximum slope length was used in the calculation.

Table 1. Drainage Area Characteristics

Drainage Area	Slope (ft/ft)	Slope Length (ft)	Time of Concentration (min)			
			Kirpich	SCS	Brant and Oberman	Mean
South Top Slope	0.02	1292.0	8.75	8.76	9.87	9.12
North Top Slope	0.02	564.5	4.62	4.63	7.49	5.58
South Side Slope	0.2	176.0	9.52	9.53	12.22	10.43
North Side Slope	0.2	42.0	4.88	4.89	8.95	6.24
East Side Slope	0.2	164.0	0.74	0.74	2.30	2.5*
West Side Slope	0.2	164.0	0.74	0.74	2.30	2.5*

*Time of concentration is limited to a minimum of 2.5 minutes.

Peak Discharge

One of the technical criteria for the stability of the disposal cell is acceptable erosional stability from extreme storm events (10 CFR 40, Appendix A). NRC has interpreted this criterion to be able to safely pass the peak runoff from storms up to the PMP event (Johnson 2002). The PMP event has a 1-hour depth of 8.2 inches, and a 15-minute depth of 7.1 inches ("Site Drainage—Hydrology Parameters" calculation, Draft RAP Attachment 1, Appendix E). For events with durations less than 15 minutes, precipitation depths as a percent of the 1-hour PMP are estimated using the following formula, as given in Table 4.1 of the UMTRA TAD (DOE 1989):

$$\%PMP_{1-hour} = \frac{RD}{0.0089RD + 0.0686}$$

where: RD = rainfall duration (minutes).

The precipitation depth of any given storm duration is then calculated as:

$$PD_{PMP} = \%PMP_{1-hour} \times PMP_{1-hour}$$

where: PD_{PMP} = precipitation depth of the PMP storm with duration equivalent to the time of concentration (inches).

The rainfall intensity is calculated for a rainfall duration equivalent to the time of concentration for the drainage basin. Rainfall intensity (inches per hour) is calculated as follows:

$$I = \frac{\Pr ecDepth(in) \times 60}{\Pr ecDur(\min)}$$

Peak flow per unit width was calculated as specified in the UMTRA TAD.

$$q = \frac{CIL}{43200}$$

where:

q = unit discharge (cubic feet per second per foot [cfs/ft]),
C = runoff coefficient = 1.0,
I = rainfall intensity (inches per hour), and
L = slope length (ft).

A runoff coefficient of 1.0 is used for PMP conditions, as discussed in UMTRA TAD (section 4.1.3).

Table 2 shows the results of the PMP unit discharge calculations in cubic feet per second per foot (cfs/ft) for the areas shown in Figure 1.

Table 2 Results of PMP Unit Discharge Calculation

Drainage Area Description	Average T_c (min)	Percent $PMP_{1\text{-hr}}$	Prec D (inches)	Intensity (inches/hr)	Unit Discharge, q (cfs/ft)
South Top Slope	9.12	60.9	5.0	32.8	0.98
North Top Slope	5.58	47.2	3.9	41.6	0.54
South Side Slope	10.43	64.6	5.3	30.5	1.02
North Side Slope	6.24	50.3	4.1	39.6	0.55
East Side Slope	2.5*	27.5	2.3	54.2	0.20
West Side Slope	2.5*	27.5	2.3	54.2	0.20

Rock Size (D50) Calculation:

The required rock size on the top slopes was calculated using the Safety Factor method, as recommended in NUREG/CR-4620 (Nelson et al. 1986) and NUREG-1623 (Johnson 2002) for slopes less than 10 percent. The safety factor against erosion for any given rock is calculated as:

$$SF = \frac{\cos\alpha \times \tan\phi}{\eta \times \tan\phi + \sin\alpha}$$

where:

α = angle of slope measured from horizontal,
ϕ = angle of repose of rock, and
η = stability number.

The stability number is calculated as:

$$\eta = \frac{21\tau_o}{(S_s - 1)\gamma D}$$

where:

τ_o = bed shear stress (psf),
S_s = specific weight of the rock,
γ = specific weight of water,
D = representative rock size (ft),

and:

$$\tau_o = \gamma ds$$

where:

d = depth of flow (ft), and
s = slope (ft/ft).

The depth of flow is calculated using Manning's equation

$$q = \frac{1.486 d R^{\frac{2}{3}} \sqrt{S}}{n}$$

where:

q = unit flow (cfs/ft),
d = depth of flow (ft),
R = hydraulic radius = d for wide channels,
S = slope (ft/ft), and
n = Manning's n

Manning's *n* is computed using procedures discussed by Abt et al. (1987) as follows:

$$n = 0.0456 * (D_{50} * S)^{0.159} \qquad (1)$$

where: *n* is Manning's *n*,
D_{50} is the mean riprap diameter in inches, and
S is the channel slope (ft/ft).

For a PMP event, a factor of safety slightly greater than 1.0 is recommended (Nelson et al. 1986). A factor of safety of 1.01 was used in these calculations. The method assumes uniform sheet flow across the entire drainage basin. The peak unit discharges due to the PMP (Table 2) were used to represent flow conditions on the top slope. The flow per unit width was multiplied by 3 to account for potential flow channelization. The angle of repose of 37° and specific gravity of rock (2.65) were assumed. The minimum thickness of rock on the top slope should be 2 times the D50 (Johnson, 2002).

The rock size (D50) required on the side slopes was calculated using the Abt and Johnson (1991) method, as discussed in NUREG-1623 (Johnson 2002). This method is recommended for slopes greater than 10 percent. The D_{50} rock size using the Abt and Johnson method is calculated as:

$$D_{50} = 5.23S^{0.43}q^{0.56}$$

where:

q = design unit discharge (cfs/ft), and
S = Slope (ft/ft).

The method assumes uniform sheet flow across the entire drainage basin. The peak unit discharges due to the PMP (Table 2) were used to represent flow conditions on the top slope. This flow was multiplied by a concentration factor of 3 to account for flow channelization and by 1.35 to account for the ratio of stone movement to stone failure (Abt and Johnson, 1991). The angle of repose and specific gravity of rock were assumed and will need to be adjusted (if necessary) with actual source characteristics.

The rock protection layer thickness should be at least 1.5 to 2 times the median rock size.

Rock Size (D50) on Cell Aprons

Additional erosion protection will be provided for runoff from the side slopes of the disposal cell with rock aprons. The perimeter apron will: (1) serve as an impact basin and provide for energy dissipation of runoff, (2) provide erosion protection, and (3) transition flow from side slopes to natural ground. The median rock size required in the perimeter apron was calculated using the equations derived by Abt et al. (1998) as outlined in NUREG 1623 (Johnson 2002) as follows:

$$D_{50} = 10.46S^{0.43}q^{0.56}$$

where S is the side slope above the apron, and q_d is the design unit discharge. The computed unit discharge was multiplied by three to account for potential flow channelization and by 1.35 to protect against rock movement as well as catastrophic failure (Johnson, 2002 and Abt et.al. 1998) The thickness of the rock apron should be at least three times the D50 (Johnson, 2002) and the width of the apron at least 15 times the D50.

Scour at Aprons:

The maximum scour depth for a PMP storm was calculated using procedures outlined in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (DOT 1983). For discharge from a rock apron onto natural ground the scour depth is computed as:

$$D_s = \alpha_e y_e \left[\frac{\rho V^2}{\tau_c}\right]^{\beta}\left[\frac{t}{t_o}\right]^{\theta}$$

where

Ds = scour depth (ft)
α_e = 1.37
τ_c = critical tractive shear
β = 0.18
θ = 0.10
t = time duration of peak flow duration or 30 minutes if unknown
t_o = base time used in the experiments to determine the coefficients (316 minutes is the default)
$y_e = (A/2)^{1/2}$ where A is the cross sectional area of flow

and $\tau_c = 0.001(S_v + 8618)\tan(30 + 1.73 * PI)$

where

S_v = saturated shear strength (assumed 1.4 for native soils)
PI = plasticity index (5 for native soils)

For these calculations, the flow per unit width was multiplied by 3 to account for potential flow concentration. This design flow was assumed to exit the apron in a v-shaped channel with side slopes of 2H to 1V. The Manning n value was computed from the D50 of the rock on the apron using the equation from Abt et. al. (1987) as follows:

$$n = 0.0456 * (D_{50} * S)^{0.159} \quad (1)$$

where: *n* is Manning's *n*,
D_{50} is the median riprap diameter in inches, and
S is the channel slope (ft/ft).

The results of these calculations are summarized in Table 3.

Table 3 Calculated rock sizes and thickness for erosion protection.

Drainage Area	Unit PMP Discharge (cfs/ft)	Conc Factor	Stone Movement Ratio	D50 (in)	Min Layer Thickness (in)	Min Apron Width (ft) 10 ft min.	Scour Depth (ft)
South Top Slope	0.98	3		1.8	3.6		
North Top Slope	0.54	3		1.2	2.4		
South Side Slope	1.02	3	1.35	5.8	11.6		
North Side Slope	0.55	3	1.35	4.1	8.2		
East Side Slope	0.20	3	1.35	2.3	4.6		
West Side Slope	0.20	3	1.35	2.3	4.6		
South Apron	1.02	3	1.35	11.6	34.7	15	1.66
North Apron	0.55	3	1.35	8.2	24.5	10	1.18
East Apron	0.20	3	1.35	4.7	14.0	10	0.67
West Apron	0.20	3	1.35	4.7	14.0	10	0.67

Over sizing may be required for rounded rock or for durability considerations. The width of the apron should be a minimum of 15 times the median rock size or construction width. Rock apron thickness should be a minimum of 3 times the median rock size or greater than the calculated scour depth. (Johnson, 2002)

Bedding Requirements

NUREG-1623, Appendix D (Johnson 2002), recommends a filter or bedding layer be placed under erosion protection if interstitial velocities are greater than 1 ft/sec, in order to prevent erosion of the underlying soils. Bedding is not required if interstitial velocities are less than 0.5 ft/sec, and recommended depending on the characteristics of the underlying soil if velocities are between 0.5 and 1 ft/sec.

Interstitial velocities are calculated by procedures presented by Abt and Johnson (1991) as given by the following equation:

$$V_i = 0.23 * (g * D_{10} * S)^{\frac{1}{2}}$$

where:

- V_i = interstitial velocities (ft/s),
- g = acceleration of gravity (ft/s^2),
- D_{10} = stone diameter at which 10 percent is finer (inches), and
- S = gradient in decimal form.

The D10 is still to be determined, but assuming it will be equal to ½ the D50, the following results are obtained. These results will be refined when the source and size distribution of the rock is determined, but it is expected that a bedding layer will be required at least on the north and south side slopes and probably on the east and west.

Table 4. Results of Bedding Requirements

Location	D10 (in)	Slope	Interstitial Velocity (fps)
South Top Slope	0.9	0.02	0.18
North Top Slope	0.6	0.02	0.14
South Side Slope	2.9	0.2	0.99
North Side Slope	2.05	0.2	0.84
East Side Slope	1.15	0.2	0.63
West Side Slope	1.15	0.2	0.63
South Apron	5.8	0.02	0.44
North Apron	4.1	0.02	0.37
East Apron	2.35	0.02	0.28
West Apron	2.35	0.02	0.28

References:

10 CFR 40. U.S. Nuclear Regulatory Commission (NRC), "Domestic Licensing of Source Material," Appendix A, *Code of Federal Regulations*, February 2007.

40 CFR 192. U.S. Environmental Protection Agency (EPA) "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *Code of Federal Regulations*, February 2007.

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