DOE-EM/GJ1270-2006

Office of Environmental Management – Grand Junction

MOAB UTAH UMTRA

UMTRA Project

Revised Draft 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

June 2007

U.S. Department of Energy

Office of Environmental Management

Work Performed Under DOE Contract No. DE-AC01-02GJ79491
for the U.S. Department of Energy Office of Environmental Management.
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Attachment 4 Water Resources Protection
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End of current text

Acronyms

Act	Floyd D. Spence National Defense Authorization Act
ASTM	American Society for Testing and Materials
Atlas	Atlas Minerals Corporation
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter
cm/s	centimeter per second
cm^2/s	square centimeter 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
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FE	floating earthquake
FR	Federal Register
ft	foot/feet
FY	fiscal year
g	standard acceleration of gravity
GCAP	Ground Water Compliance Action Plan
km	kilometer
m^2	square meter
μR/h	microroentgen per hour
MCE	maximum credible earthquake
mg/L	milligram per liter
mi	mile
mi^2	square mile
NAS	National Academy of Sciences
NOAA	U.S. National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NRC	U.S. Nuclear Regulatory Commission
NRCS	U.S. National Resources Conservation Service
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 ground acceleration
PMF	probable maximum flood
PMP	probable maximum precipitation
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
SCS	U.S. Soil Conservation Service
SOWP	Site Observational Work Plan
SRP	Standard Review Plan

TAD	Technical Approach Document
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
yd^3	cubic yard

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 the *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. After reviewing the draft plan, NAS provided a list of recommendations on June 11, 2002, 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 preferred alternative for the site was selected in the Record of Decision (ROD), which was published in the FR on September 21, 2005 (70 FR 55358). The selected alternative for surface remediation was removal of tailings and associated residual radioactive material (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 mode of transportation for tailings between the Moab Site and Crescent Junction.

1.1 Site Background

1.1.1 Location

The Moab Processing Site is located approximately 3 miles (mi) northwest of the city of Moab, in Grand County, Utah, adjacent to the Colorado River (Figure 1–1).

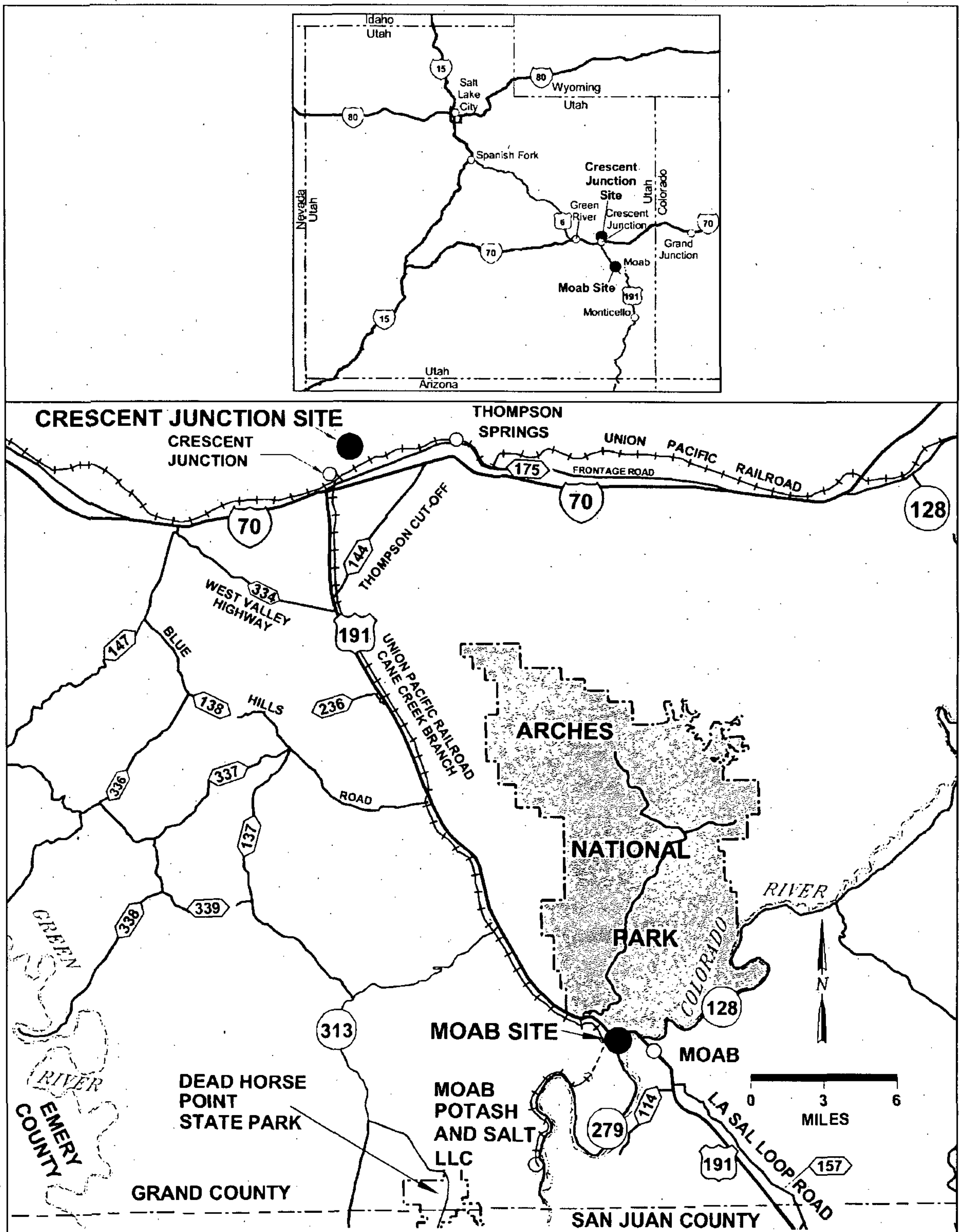

Figure 1–1. Location of the Moab and Crescent Junction Sites in Grand County, Utah

The processing site is on the Moab 7.5-minute topographic quadrangle 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 mi north of the Moab Site, and approximately 1 mi 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 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 withdrawal area (Figure 1–3).

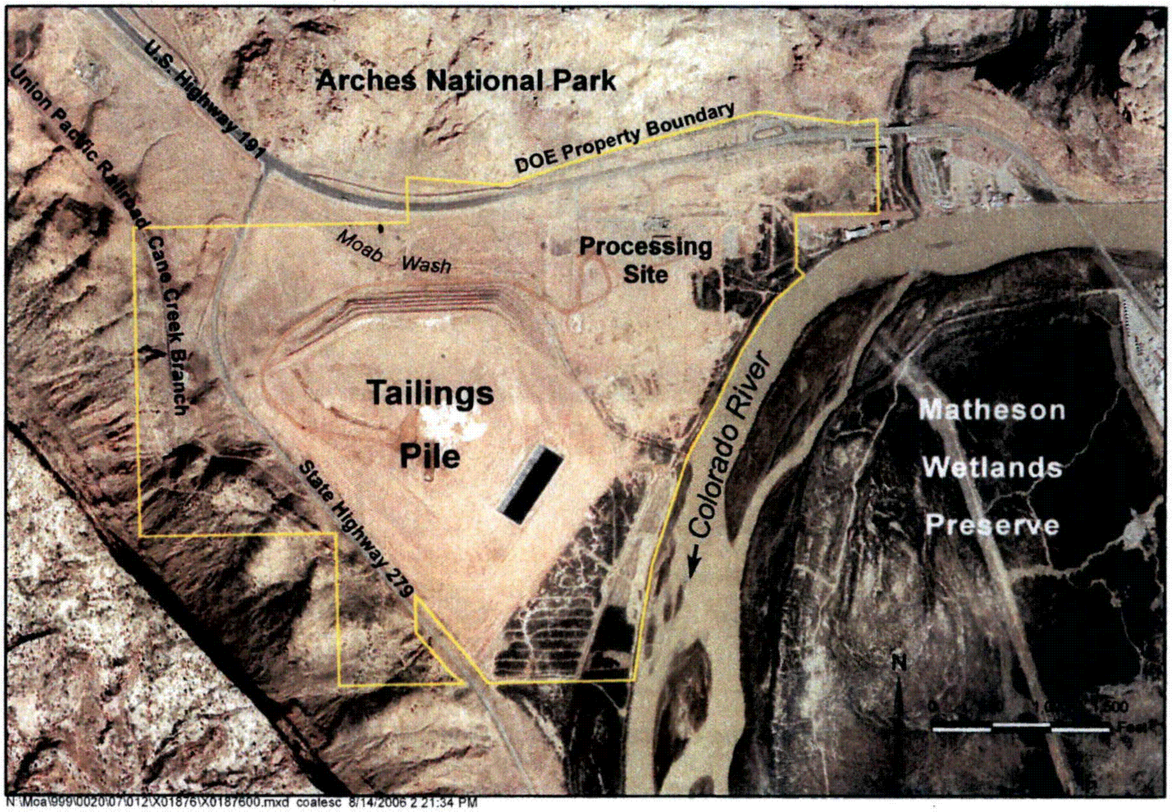

Figure 1–2. Aerial Photograph of the Moab Processing Site

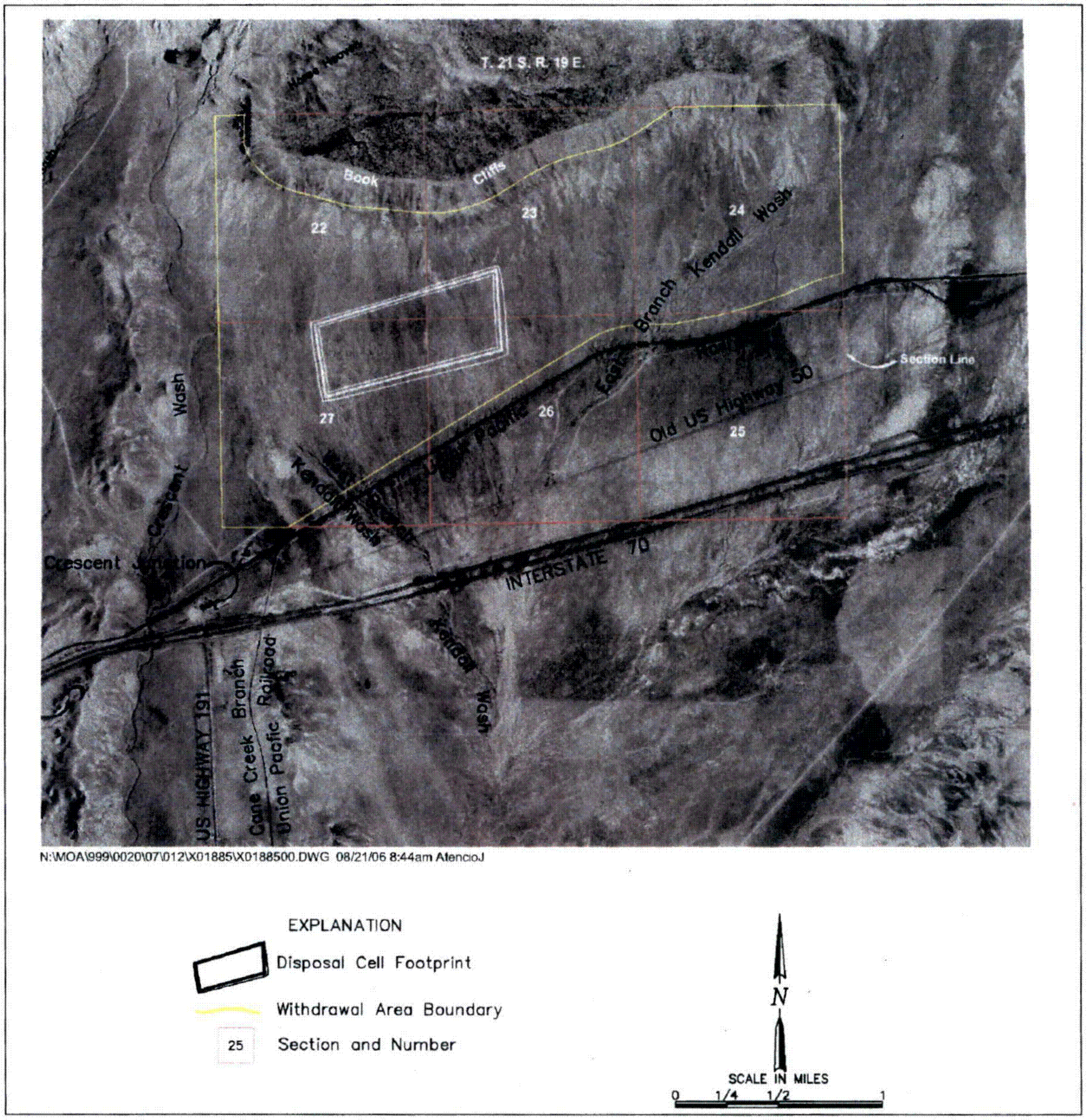

Figure 1–3. Aerial Photograph of the Crescent Junction Disposal Site and Surrounding Area

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 an estimated 10.5 million tons of 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 mi in diameter, averages 94 feet (ft) in height (at an elevation of 4,076 ft) above the Colorado River floodplain and is about 750 ft 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 the uranium mill tailings and associated RRM from the Moab Processing Site was relocation 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. DOE selected rail as the mode of transportation because, compared to truck transportation, rail has a lower accident rate, lower potential impacts to wildlife (including threatened and endangered species), and lower fuel consumption. Compared to a slurry pipeline, rail transportation would have a much lower water demand and would avoid landscape scars caused by pipeline construction, which could create moderate contrasts in form, line, color, and texture with the surrounding landscape..

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 RRM at the Moab Site and vicinity properties has a total 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 and contaminated materials to the Crescent Junction disposal cell. Rail cars will transport contaminated materials from the processing site to the disposal site along the route shown in Figure 1–1.

Disposal will consist of constructing an approximately 250-acre engineered cell partially below grade. The disposal cell is generally trapezoidal in shape. The cell is designed for about half 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 and balancing the quantity of shale that is required for constructing perimeter berms and the radon barrier. Excess colluvial material will be used as backfill at the processing site, as interim cover and freeze-thaw layer, or wasted on the downhill face. The north side of the cell, near the base of the Book Cliffs, intersects the existing slope to provide a 0.5 percent grade to the west. This reduces the velocity of runoff against the north toe of slope, while maintaining the existing drainage path to the West Branch of Kendall Wash. The west and east sides are canted inward slightly to provide sheet flow for side slope runoff away from the toe of the side slopes. The top slope grade is 2 percent from north to south, matching the existing ground slope. This causes the height of the cell to be uniform relative to the existing ground. To prevent "bathtubbing" in the bottom of the cell, the cell cover is less permeable than the bottom of the cell.

1.2 EPA Standards

As required by the 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 their 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 in order 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.

The Remedial Action Selection (RAS) Report 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 prepared after surface remediation is largely complete.

1.3 Scope, Content, and Organization

The purpose of the RAP is to document the remedial activities necessary to move the contaminated materials from the Moab Processing Site to stabilization at the Crescent Junction Disposal Site. This involves assessment of contaminated materials at the Moab Processing Site, 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 RAS Report provides a summary level description of the remedial action and a discussion of technical findings made 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 and data are included with reference given to the supporting documents, which are included in RAP Attachments. The RAS Report does not contain design details; these are available in supporting documents, reports, and calculations.

The information in this RAS Report is what was presented by DOE to NRC during meetings held in April, June, and December 2006. Comments received as a result of those meetings and from NRC review of the draft RAP submitted in August 2006 have been incorporated into this RAS Report. A comment resolution/response is included as Appendix A to this RAS Report and explains how each comment was resolved and has been addressed in this revised version of the RAP.

The RAP consists of this RAS Report and the following attachments, which contain calculation sets and supporting information covering various aspects of the remedial action:

- Attachment 1—Disposal Cell Design Specifications
- Attachment 2—Geology
- Attachment 3—Ground Water Hydrology
- Attachment 4—Water Resources Protection
- Attachment 5—Field and Laboratory Results (2 volumes)

Table 1–1 is a listing of all calculation sets contained within each RAP 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 that are not reported in the RAP. The SOWP (DOE 2003) assesses ground water conditions at the Moab Processing Site and provides alternatives for ground water cleanup and complying with the EPA ground water protection standards in 40 CFR 192.

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 RAP Attachments

Calculation Cross-Reference Guide		
Location	**Calculation Number**	**Calculation Title**
Attachment 1: Disposal Cell Design Specifications		
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
Attachment 2: Geology		
Appendix A	MOA-02-04-2007-1-05-01	Site and Regional Geology – Results of Literature Research
Appendix B	MOA-02-04-2007-1-01-01	Surficial and Bedrock Geology of the Crescent Junction Disposal Site
Appendix C	MOA-02-04-2007-1-06-01	Site and Regional Geomorphology – Results of Literature Research
Appendix D	MOA-02-04-2007-1-07-01	Site and Regional Geomorphology – Results of Site Investigations
Appendix E	MOA-02-04-2007-1-08-01	Site and Regional Seismicity – Results of Literature Research
Appendix F	MOA-02-04-2007-1-09-02	Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration
Appendix G	MOA-02-04-2007-1-02-01	Photogeologic Interpretation
Attachment 3: Ground Water Hydrology		
Appendix A	MOA-02-02-2006-2-07-00	Saturated Hydraulic Conductivity Determination of Weathered Mancos Shale
Appendix B	MOA-02-03-2006-2-10-00	Field Permeability "Bail" Testing
Appendix C	MOA-02-03-2006-2-06-00	Field Permeability "Packer" Testing
Appendix D	MOA-02-04-2006-2-03-00	Hydrologic Characterization – Ground Water Pumping Records
Appendix E	MOA-02-05-2006-2-13-00	Hydrologic Characterization – Vertical Travel Time to Uppermost (Dakota) Aquifer
Appendix F	MOA-02-02-2007-3-01-00	Geochemical Characterization – Radiocarbon Age Determinations for Ground Water Samples Obtained From Wells 0203 and 0208
Appendix G	MOA-02-06-2006-2-15-00	Infiltration Modeling for Alternative and UMTRA Cover Designs
Appendix H	MOA-02-06-2007-2-14-00	Hydrologic Characterization – Lateral Spreading of Leachate
Attachment 4: Water Resources Protection		
Appendix A	MOA-02-06-2006-5-24-00	Material Placement in the Disposal Cell
Appendix B	MOA-02-06-2006-3-05-00	Geochemical Attenuation and Performance Assessment Modeling
Attachment 5: Field and Laboratory Results, Volume I		
Appendix A	MOA-02-03-2006-1-03-00	Corehole Logs for the Crescent Junction Site
Appendix B	MOA-02-03-2006-1-11-00	Borehole Logs for the Crescent Junction Site
Appendix C	MOA-02-03-2006-1-04-00	Geophysical Logs for the Crescent Junction Site
Appendix D	MOA-02-03-2006-1-10-00	Test Pit Logs for the Crescent Junction Site
Appendix E	MOA-02-03-2006-4-01-00	Geotechnical Properties of Native Materials
Appendix F	MOA-01-06-2006-5-22-00	Cone Penetration Tests for the Moab Processing Site
Appendix G	MOA-02-05-2006-4-07-00	Seismic Rippability Investigation for the Crescent Junction Site
Appendix H	MOA-02-03-2007-3-04-01	Background Ground Water Quality for the Crescent Junction Site
Appendix I	MOA-01-08-2006-4-08-00	Boring and Test Pit Logs for the Moab Processing Site
Appendix J	MOA-01-08-2006-4-09-01	Geotechnical Laboratory Testing Results for the Moab Processing Site
Appendix K	MOA-02-04-2007-4-03-01	Supplemental Geotechnical Properties of Native Materials
Attachment 5: Field and Laboratory Results, Volume II		
Appendix L	MOA-02-08-2006-1-06-00	Compilation of Geologic and Geophysical Logs
Appendix M	N/A	Radiological Assessment for Non-Pile Areas of the Moab Project Site
Appendix N	MOA-02-05-2007-4-04-00	Supplemental Geotechnical Properties of Tailings Materials from the Moab Processing Site

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 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 use din 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.

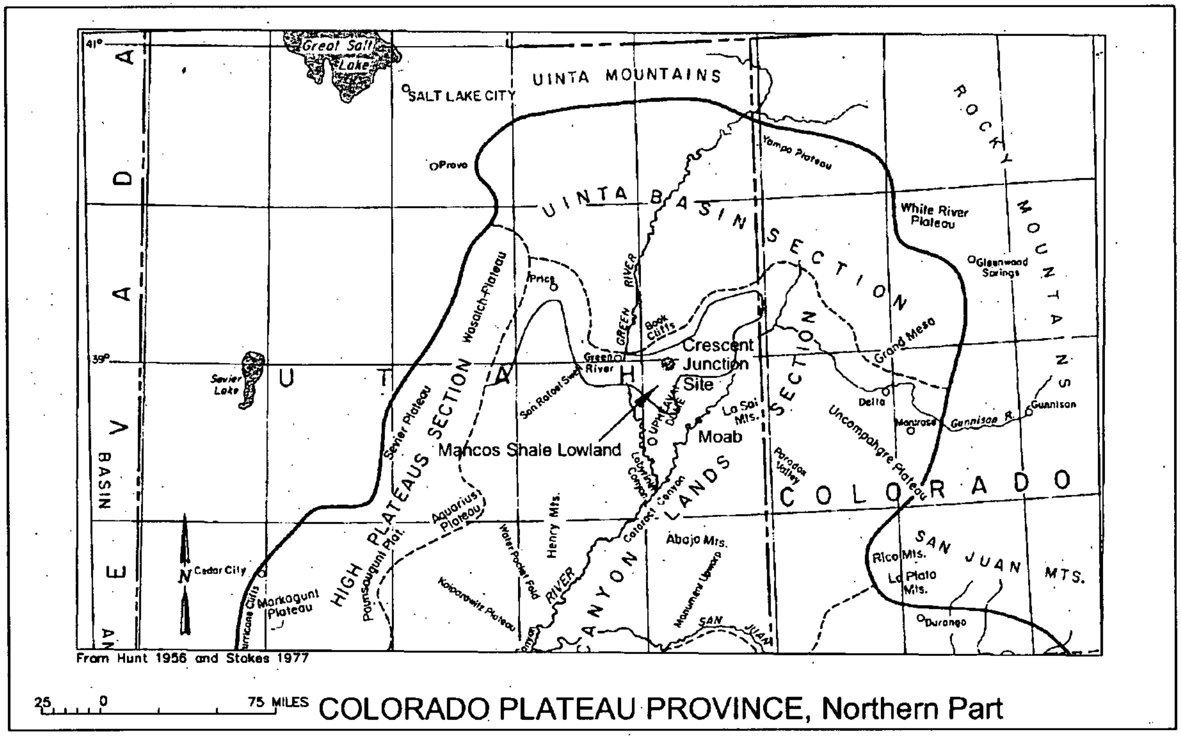

Figure 2–1. Physiographic Setting of the Crescent Junction Site

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 2 mi, from an elevation of about 5,100 ft to the north to about 4,900 ft 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 mi 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 ft of continental sedimentary rocks of Mesozoic age underlie the marine Mancos Shale, which also is about 4,000 ft thick. The part of the Mancos Shale underlying the immediate site area is about 2,400 ft 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 Neogene time. 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.

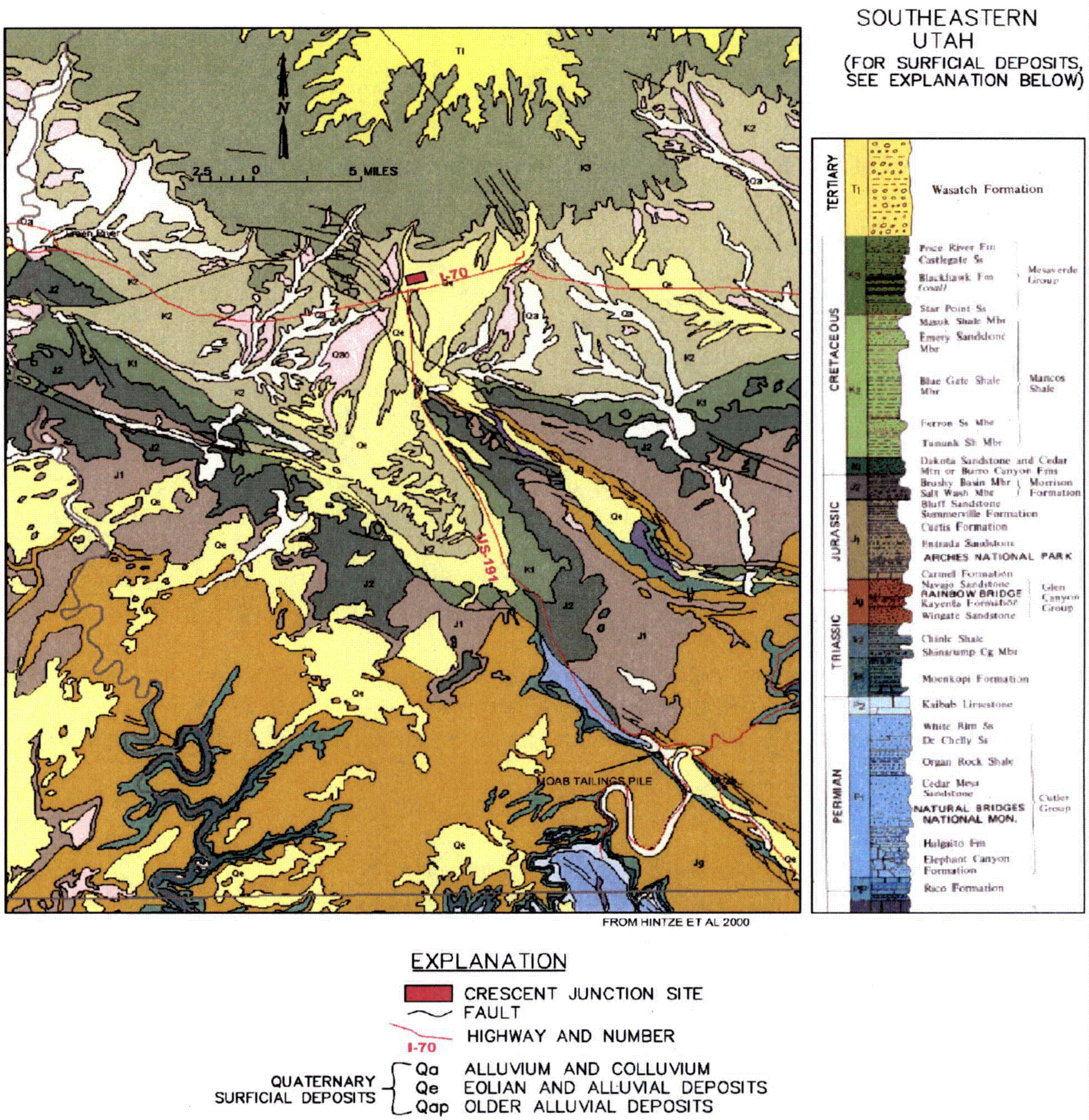

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Figure 2–2. Regional Geology of the Crescent Junction Site

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 0.12g 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 0.5g. 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 0.21g 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 250-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 ft 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 ft 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 ft 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 ft 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 ft 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 ft 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 to 400 ft thickness. It is therefore estimated that approximately 2,400 ft of Mancos Shale underlies the center of the proposed disposal cell.

Natural fractures are mostly in the top 50 ft 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 ft 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 to 12 ft thick, but can be as much as 25 ft . 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 ft 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 900 ft 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. Rock armoring of this drainage path will be 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 ft 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 mi 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 ft at the closest point) to not affect the disposal cell. Swelling clay in the Mancos Shale also poses a potential 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.

Rock-fall debris covers some of the badlands slope as talus along the south side of the 800-ft-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 900 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 5 ft 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.

Swelling clay in the Mancos Shale poses a potential geologic hazard at the site. Swelling is caused by the presence in Mancos Shale of the clay mineral, montmorillonite, which originated from volcanic ash that was altered after it fell into the Western Interior Seaway. Fresh and slightly weathered Mancos Shale can swell considerably when wetted and may affect building foundations and paved highways. Because no permanent concrete-slab structures and no paved roads are planned for the disposal site, the swelling clay in the Mancos Shale should not pose a geologic hazard. Soil derived from Mancos Shale has the characteristic of moderate swelling, but this will not negatively affect the ability of the disposal site to stabilize the tailings.

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.

Step 1. FE

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 1 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 0.22g. 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 >0.1g 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 0.22g. 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 0.13g. 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 0.22g.

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 0.22g.

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-ft 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 2-mi-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 ft into bedrock; most fractures were in the top 50 ft of bedrock, representing the weathered Mancos Shale.

Potential geologic hazards at the site consist of mass movement processes (rock falls) and swelling clays in the Mancos Shale. These potential hazards would not pose a problem for location of the disposal cell at the Crescent Junction Site. 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. However, sheet wash from the north will have to be redirected westward around the disposal cell, and 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.

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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 ft 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 free-flowing ground water.

The alluvial and colluvial materials are underlain by the Mancos Shale, which is approximately 2,400 ft 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 ft. 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, more regional aquifer systems. It also appears to be disconnected from sources of freshwater recharge. 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 ft 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 mi 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.

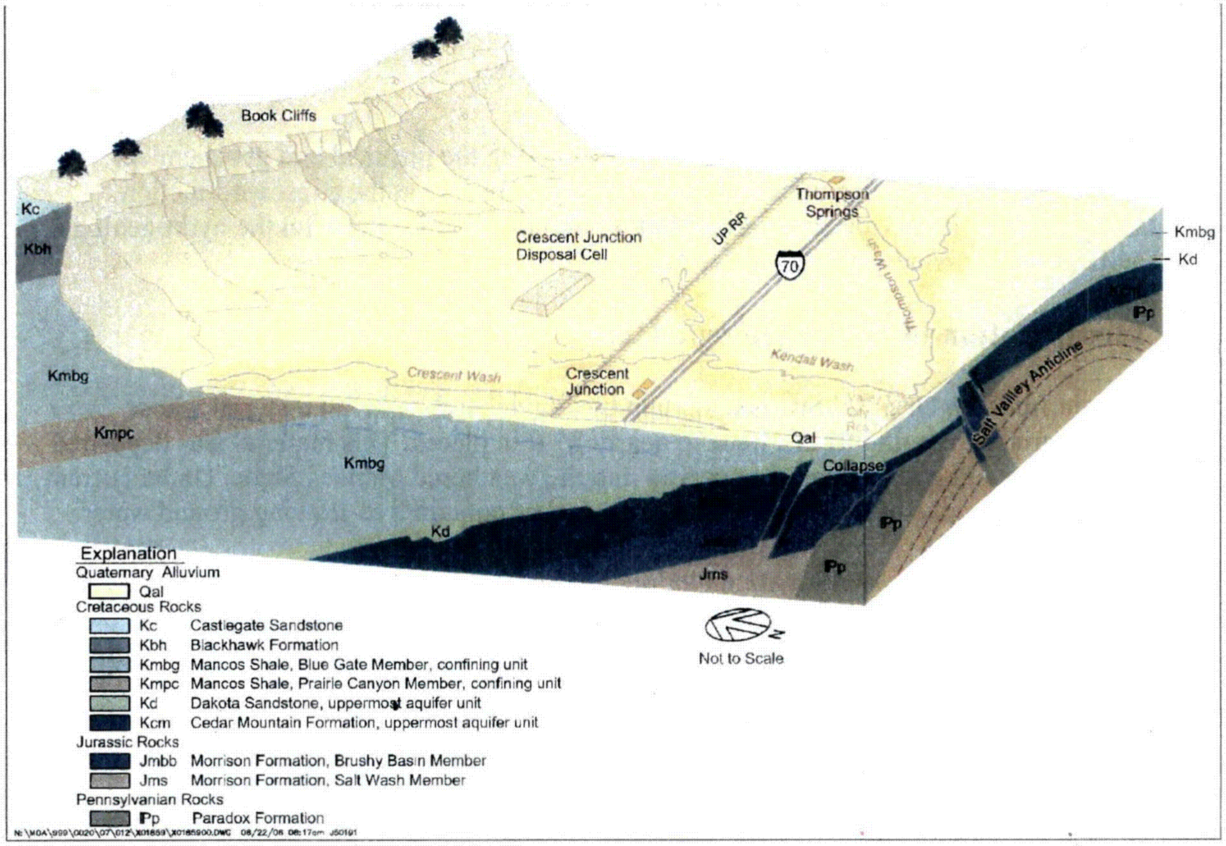

Figure 3–1. Schematic Block Diagram Depicting the Major Hydrogeologic and Topographic Features at the Crescent Junction, Utah, Disposal Site

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 mi 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 6 mi 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 mi southeast of the site.

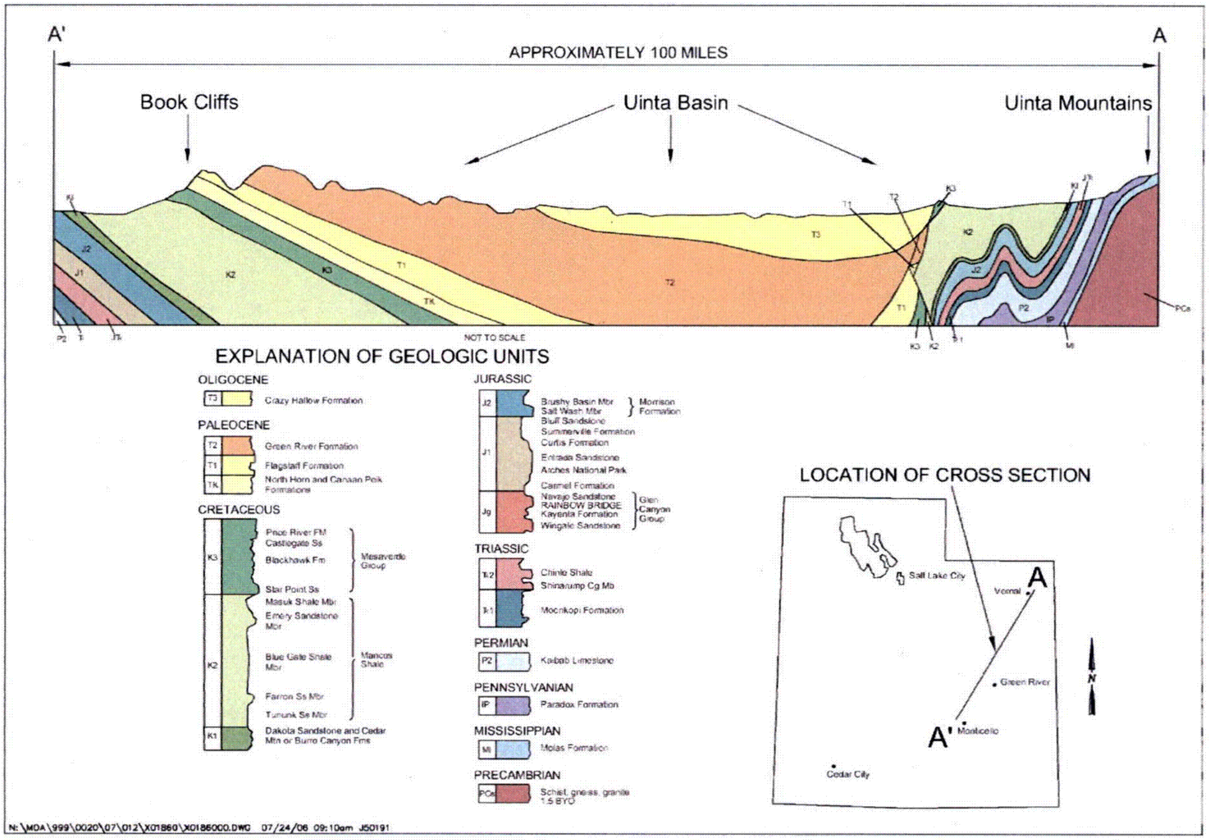

Figure 3–2. Regional Scale Cross Section Depicting Regional Hydrogeologic Elements, Crescent Junction Site, Utah (modified from Hintze et al. 2000)

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 of the RAP, respectively.

3.5 Water Use

There are no private or municipal wells within 2 mi of the Crescent Junction Disposal Site. Figure 3–3 illustrates the occurrence of water resources in the Crescent Junction area.

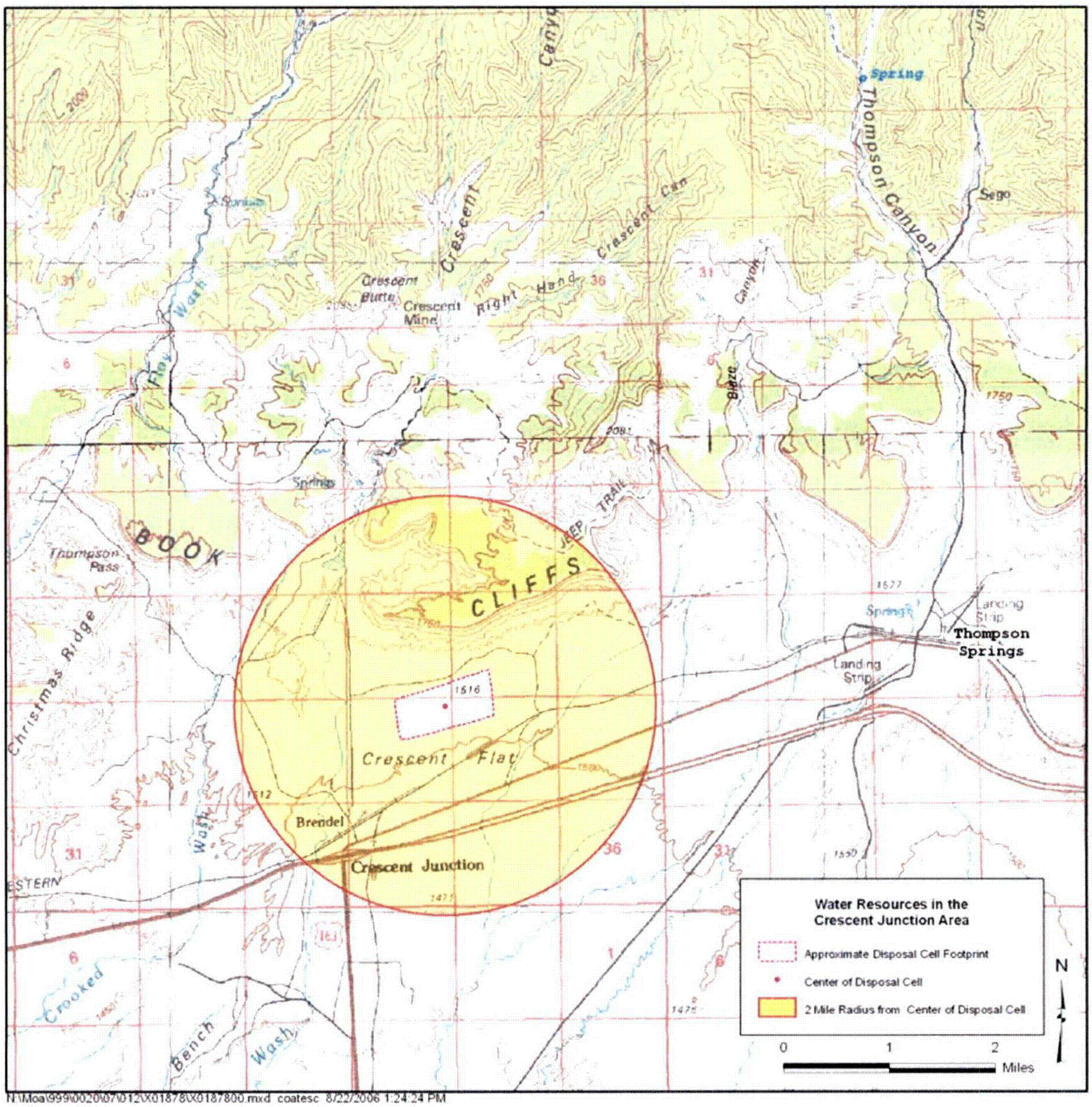

Figure 3–3. Water Resources in the Vicinity of Crescent Junction, Utah

The nearest municipal water supply to the Crescent Junction Disposal Site is in Thompson Canyon, located approximately 7 mi 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 3-inch water line, which extends from Thompson Springs and serves residential and commercial customers in the vicinity of the Crescent Junction Disposal Site.

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, the mill tailings and associated RRM, and potential contaminated vicinity properties materials. 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 Attachments 1 and 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 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 ft 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 ft 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 ft in the Mancos Shale. Conventional geotechnical soil sampling was performed in the unconsolidated soil zone, and continuous HQ core was obtained from the bedrock. Three additional, shallow coreholes (0211 through 0213) were drilled to a maximum depth of 42 ft 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-ft long and geophones were spaced at approximately 10-ft 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.

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 ft below the surface; twelve test pits (0621 to 0632) were dug to a depth of 20 ft below the surface; and 15 CPT soundings with pore-pressure dissipation tests (0381 through 0395) were advanced to a maximum depth of 81.9 ft 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 can reach a maximum thickness of nearly 25 ft covers most of the disposal site. These deposits cover Mancos Shale bedrock, which has a thickness of approximately 2,400 ft beneath the center of the disposal cell.

The Quaternary deposits are typically 10 to 12 ft 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 ft 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 ft 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 ft into the Mancos Shale and are absent below a depth of 100 ft 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 excavation is anticipated to be built into the upper 5 to 10 ft of 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 Attachment 1. 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 slope stability analyses are presented in Attachment 1, Appendix C. These analyses show that for both static and dynamic conditions, the slopes of the disposal cell, and the cell foundation will not fail or otherwise adversely affect the remedial action. 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.

<u>Adopted Design Properties</u>

Attachment 1, Appendix C, lists the geotechnical design parameters used in the stability analyses. This calculation describes in detail the properties of the soils and rocks that comprise the slopes and the field and laboratory data used to establish design parameters. The geotechnical properties of the clean-fill dike and cover materials used in construction of the disposal cell were tested at densities and moisture contents that are consistent with the placement specifications. Geotechnical properties of the tailings materials were assumed based on available test results on Moab mill tailings and literature values for uranium mill tailings. Assignment of geotechnical parameters for the slope stability analysis followed conventional geotechnical engineering practice and was done in accordance with provisions in the SRP and the TAD.

Method of Analysis

Slope stability analyses were performed using limit equilibrium methods with the aid of the computer program SLOPE/W (Geo-Slope/W 2004). Spencer's method was used for these analyses because it considers both force equilibrium and moment equilibrium in the factor-of-safety calculation. Additionally, an infinite slope stability analysis was also performed for potential shallow failure surfaces. Seismic conditions were analyzed under pseudostatic conditions. A PHA of 0.22g was determined based on the predicted seismicity of the region (Attachment 2, Appendixes E and F). Amplification of the PHA is not expected because of the relatively stiff character of the Mancos Shale underlying the site. The horizontal coefficients for both the long-term and short-term conditions were determined by calculating two thirds and one half (respectively) of the PGA, resulting in values of 0.15g and 0.11g, respectively. The use of the pseudostatic method is an acceptable method, because of the use of materials that do not lose shear strength with seismic deformation.

Results of Analysis

The minimum factors of safety against failure of the slopes of the disposal cell are summarized in Table 4–1. These factors of safety are equal to or exceed the acceptable values established in the SRP and the TAD. All cuts and grubbed slopes will be restored to prevent long-term instability. DOE concludes that the slopes will be stable in accordance with the requirements of 40 CFR 192.02(a) for long-term stability.

Table 4–1. Summary of Slope Stability Analysis

Loading Condition	Calculated Factor of Safety
End-of-construction:	
Static	1.7
Pseudostatic (k_h = 0.11g)	1.1
Infinite Slope (static)	1.7
Infinite Slope (pseudostatic)	1.1
Long-term:	
Static	2.4
Pseudostatic (k_h = 0.15g)	1.0
Infinite Slope (Static)	2.4
Infinite Slope (Pseudostatic)	1.1

K_h = pseudostatic coefficient

4.2.2 Settlement

Evaluation of tailings settlement in the disposal cell is presented in Attachment 1, Appendix D. The evaluation included the magnitude of post-construction tailings settlement, the extent of differential tailings settlement, and the impact of differential tailings settlement on cover performance. The evaluation results showed that estimated post-construction tailings settlement is relatively low, due to the methods of mixing, placement, and compaction of the tailings in the plans for relocation to the disposal cell. Differential settlement of the tailings is limited to areas of the disposal cell with varying tailings thickness and loading (such as at the perimeter of the cell), and the tensile strain calculated from the estimated differential settlement would not result in cracking of the radon barrier or other cover system materials.

Tailings settlement was evaluated under anticipated tailings loading or stress changes from construction and reclamation activity. These stress changes can be caused by: (1) the weight of construction equipment; (2) the loading due to the reclamation cover; and (3) lowering of the zone of saturation in the tailings. In this case, the tailings will be placed in the disposal cell as an unsaturated material, spread in lifts, and rolled with conventional construction equipment. At other Title I sites with relocated tailings the areas of concern for post-construction settlement are limited to transition zones between tailings and embankment materials or subsoils, or zones between tailings and contaminated soils (such as described in Larson and Keshian 1988), where differential settlement may occur.

Analysis of tailings settlement was based on the anticipated method of placement and cover system loads on the tailings, Moab tailings test results, and published data on uranium tailings characteristics.

The magnitude of primary and secondary settlement of the tailings due to the loading of subsequent tailings and cover materials was calculated from testing data on Moab tailings and data in Keshian and Rager (1988) on Title I uranium tailings samples. Estimates of both primary and secondary settlement at the top of the tailings profile were relatively low (1.2 and 0.8 ft, respectively).

The multi-year construction schedule for the disposal cell provides significant time for tailings drying and settlement prior to cover placement. Tailings will be placed in regions of the cell in lifts, compacted, and covered with interim cover. These regions will subsequently be covered with the soil cover system. Due to the construction schedule, primary settlement of one area of tailings may be nearly complete by the time the cover is placed over this area of tailings.

Cover cracking was evaluated by comparison of allowable strain for the cover materials (Caldwell and Reith 1993; Larson and Keshian 1988) with maximum calculated strain due to differential settlement in the cover. The calculated strain was lower than the allowable tensile strain for the cover soil, indicating acceptable cover performance. In addition, the relatively thick cover may accommodate differential settlement without detrimental effects.

4.2.3 Liquefaction Potential

Evaluation of tailings liquefaction potential in the disposal cell is presented in Attachment 1, Appendix D. Although tailings liquefaction would require relatively loose tailings under saturated conditions, the evaluation was conducted in the unlikely event that the tailings become saturated.

Although the tailings will be placed in the disposal cell in an unsaturated condition, downward migration of porewater or inclusion of meteoric water may create zones in the tailings with saturated conditions. The potential liquefaction of saturated zones of the tailings was checked with standard procedures outlined in Day (1999). This involves comparison of the seismic stress ratio due to the design seismic event with the seismic stress ratio that would cause liquefaction of the tailings at a specific depth of analysis.

Calculations were made at the top and bottom of the tailings profile in the disposal cell. The stress ratio due to the seismic event was calculated from the peak estimated acceleration at the ground surface of 0.22g (Attachment 2, Appendixes E and F). The stress ratio required for liquefaction was based on a conservatively estimated relative density of the tailings of 50 percent, and on a tailings compaction at 90 percent of standard Proctor density (using a correlation in Holtz and Kovacs [1981]). For this relative density and two depths of analysis, the stress ratio required to cause liquefaction of the tailings was higher than the stress ratio due to the seismic event, indicating that if the tailings were to become saturated, the tailings would not liquefy under peak seismic ground acceleration conditions.

4.2.4 Cover Design

Details regarding the cover design are provided in Attachment 1, Appendixes A, B, C, D, and H. The cover design is further described in Section 5.0.

4.3 Construction Details

4.3.1 Construction Methods and Features

The construction details will be provided with the final RAP. An outline of the construction specifications is included in Appendix B. Only those specifications relevant to aspects of the remedial action directly related to meeting EPA standards are included (e.g., road signs, fences, and gates are not mentioned).

4.3.2 Testing and Inspection

The Remedial Action Inspection Plan will provide 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. The Remedial Action Inspection Plan will be submitted to NRC following DOE's hiring of a remedial action contractor. Quality assurance requirements will be in accordance to the Remedial Action Inspection Plan, the Project Quality Assurance Plan, and the Approved Design Specification requirements.

4.3.3 Construction Sequence

The general construction sequence will be determined by the remedial action contractor.

4.3.4 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, 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) which 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 RRM from the Moab mill site will be transported and placed in the disposal cell at Crescent Junction. The objective of material placement in the disposal cell will be to minimize subsequent settlement by compaction of compressible materials and filling void spaces within and around incompressible materials. The details of RRM material placement will be provided by the remedial action contractor.

Although the tailings will be dried to near–optimum moisture conditions prior to them 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 tailings under the influence of gravity. Furthermore, post-construction consolidation of the tailings will release water as the consolidation proceeds. These two components of released water constitute what is called transient drainage. DOE will monitor the accumulation of transient drainage with a standpipe tapping a sump at the downgradient toe of the disposal cell. In the event that transient drainage accumulates in the sump and reaches some action level, DOE will pump the fluid out through the standpipe. After the disposal cell is constructed, and no further water accumulates in the sump, DOE will remove the standpipe.

End of current text

5.0 Radon Attenuation

5.1 Design

The remedial action at the Moab Processing Site and the Crescent Junction Disposal Site is summarized in Section 1.0. Two cover designs have been evaluated to afford DOE maximum flexibility in developing the final cell design: (1) an UMTRA Project cover using a compacted clay radon barrier and (2) an alternative monolithic cover design. Both cover designs include a minimum 1-ft-thick interim cover placed directly on the tailings 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 is illustrated in Figure 5–1 and consists of an interim cover constructed of clean native alluvial materials to a minimum thickness of 1 ft, a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale, an 0.5-ft-thick infiltration and biointrusion layer, a 3.5-ft-thick frost protection layer that includes the 0.5-ft-thick rock mulch erosion protection layer. The thickness of the radon barrier depends on the thickness of the interim cover, since both layers reduce radon emanation. The minimum required radon barrier for the UMTRA Project cover is 3.9 ft, for a 1-ft-thick interim cover.

The alternative cover design is also shown in Figure 5–1 and consists of the same interim cover, a 0.5-ft-thick infiltration/biointrusion barrier, and a 9.3-ft-thick radon barrier that includes the 0.5-ft-thick rock mulch erosion protection layer and a frost protection layer.

The radon barrier layer for both the UMTRA Project and alternative cover designs was sized 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 alternative 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.

5.1.1 Radon/Infiltration Barrier Parameters

The radon barrier design parameters and supporting calculations were used in conjunction with the RADON model (NRC 1989a) 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. The radon barrier layers have been optimized by the RADON model (NRC 1989a) to limit the radon flux to 20 $pCi/m^2/s$ under long-term physical conditions. 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. Attachment 1, Appendix B presents the input parameters used for each model run as well as the model run results.

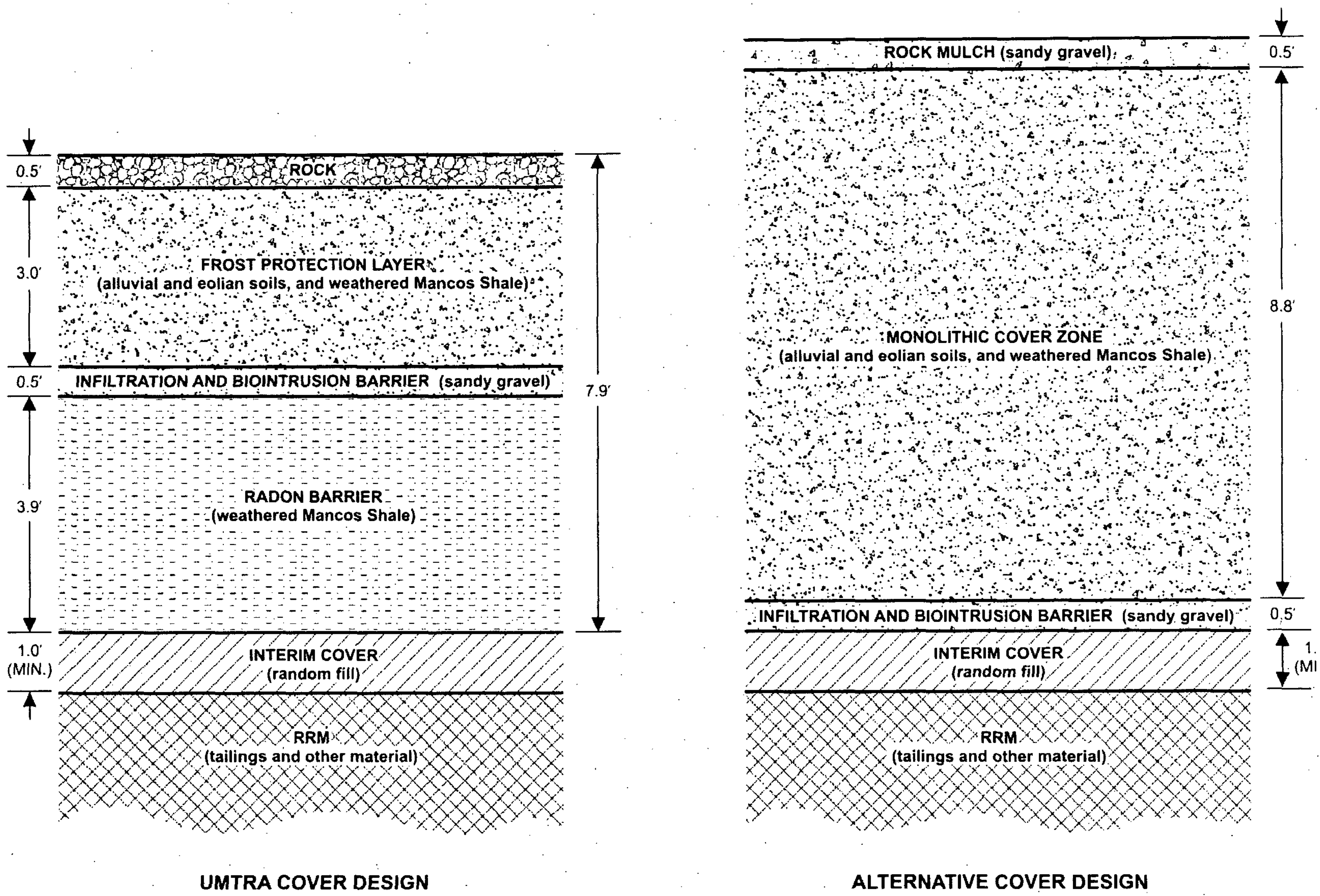

Figure 5–1. UMTRA Project Cover Design and Alternative Cover Design

Specific design parameters discussed include (1) long-term moisture content; (2) radon diffusion; (3) radon emanation; (4) density; (5) porosity; (6) layer thickness; (7) average Ra-226 activity; and (8) ambient radon concentrations. Input parameters used for the RADON model (NRC 1989a) for Crescent Junction materials are presented in Attachment 1, Appendix B.

5.1.2 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. Analyses of the sensitivity of radon barrier thickness to long-term tailings moisture content were conducted using values of 10 and 20 percent long-term moisture content.

The mean long-term moisture content of the interim cover and the alternative cover monolithic layer is modeled as 9 percent. This value is based on the mean of twenty 15-bar moisture content analyses as determined by American Society for Testing and Materials (ASTM) Method D3152 and presented in Attachment 5, Appendix E. 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, which agrees well with the measured value of site-specific soils of 9 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. This mean measured value was also evaluated for reasonableness using the Rawls and Brakenseik equation. 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.

5.1.3 Radon Diffusion

The radon diffusion coefficient used in the RADON model (NRC 1989a) 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 1984 version of RADON are not consistent with the later equations based on a much larger set of data correlating radon diffusion with soil cover materials. Therefore, this evaluation calculated the layer-specific radon diffusion coefficients based on the most current relationship using equation 9 from Rogers and Nielson (1991). These calculations are presented in Attachment 1, Appendix B.

For the tailings, the calculated radon diffusion coefficient was 0.01044 centimeters squared per second (cm^2/s), for a moisture content of 15 percent by weight and a porosity of 0.44. For sensitivity runs, tailings diffusion coefficients of 0.01873 cm^2/s (10 percent moisture content) and 0.003541 cm^2/s (20 percent moisture content) were used.

The same materials will be used to construct the interim cover and alternative cover monolithic layer (radon barrier). The calculated radon diffusion coefficient of 0.01629 cm^2/s was applied based on a moisture content of 9 percent and a porosity of 0.38. One sensitivity run considered the added benefit of the frost protection layer on radon attenuation. For this run, the frost protection layer was assumed to have the same properties as the interim cover and alternative cover monolithic layer materials.

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.

5.1.4 Radon Emanation

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

5.1.5 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, freeze/thaw protection layer, and alternative cover monolithic layer materials are all the same material and were based on compaction to 90 percent of the average modified Proctor density. The UMTRA Project cover compacted clay barrier (remolded Mancos Shale) was based on compaction to 90 percent of modified 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, freeze/thaw protection layer and alternative cover monolithic layer material. 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.

5.1.6 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 for the two design approaches. 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-ft-wide crest. Because the tailings side slope thicknesses will be far in excess of the cover requirements and with properties comparable to the cover material, radon flux through the side slopes was not modeled. Information on layer thicknesses is in Attachment 1, Appendix B.

For all model runs, a tailings thickness of 500 centimeters (cm) (16.4 ft) is used; the model output is insensitive to source term thicknesses greater than 500 cm.

The UMTRA Project cover design evaluated for radon flux consists of a 1-ft-thick interim cover constructed of clean native alluvial materials and a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale. The sand drainage and biointrusion layer, frost protection layer, and rock mulch erosion protection layer are not considered in the baseline modeling. However, an additional model run was performed for the UMTRA Project cover to illustrate the calculated radon barrier thickness required should the attenuation of radon by the frost protection layer be considered.

The alternative cover design evaluated for radon flux consists of the same interim cover and a thick monolithic radon barrier layer that includes the 6-inch-thick rock mulch erosion protection layer. The capillary barrier layer is not considered in the baseline modeling.

5.1.7 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. The average radium-226 activity for contaminated materials to be placed in the disposal cell is 707 picoCuries per gram (pCi/g).

The radium-226 activity of the alluvial materials to be used for the interim cover, alternative cover, frost protection layer, 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.

5.1.8 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 recent air samples collected at background locations have a range of 0.5 to 1.2 pCi/L.

5.2 Evaluation of the Radon Barrier

This section summarizes the manner in which the input parameters presented above were evaluated to optimize the radon barrier design.

The radon barrier was evaluated with respect to compliance 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 (NRC 1989a) were performed for both the UMTRA Project cover and the alternative cover using various combinations of cover materials and values for the moisture contents and diffusion coefficients. The RADON model runs are summarized in Attachment 1, Appendix B

5.2.1 UMTRA Project Cover

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

- Model run UMTRA Project 1a uses mean input values (including a 15 percent moisture content) for the UMTRA Project style cover with a 1-ft-thick interim cover.
- Model runs UMTRA Project 1b through UMTRA Project 1d are sensitivity runs to illustrate the effect of the interim cover thickness on the calculated radon barrier thickness to meet the 20 pCi/m^2/s flux requirement.
  - Model run UMTRA Project 1b is the same as run UMTRA Project 1a but with a 3-ft-thick interim cover.
  - Model run UMTRA Project 1c is the same as run UMTRA Project 1a but with a 5-ft-thick interim cover.
  - Model run UMTRA Project 1d is the same as run UMTRA Project 1a but with a 7-ft-thick interim cover.
- Model run UMTRA Project 2a is a sensitivity run illustrating the calculated radon barrier thickness required should the attenuation of radon by the frost protection layer be considered.
- Model runs UMTRA Project 3a and UMTRA Project 3b are sensitivity runs illustrating the effect of tailings moisture content on the calculated radon barrier thickness.
  - Model run UMTRA Project 3a is the same as UMTRA Project 1a but with the tailings moisture content set to 10 percent.
  - Model run UMTRA Project 3b is the same as UMTRA Project 1a but with the tailings moisture content set to 20 percent.

Modeling results indicate that long-term tailings moisture contents set at 10 percent and 20 percent resulted in less than 5 percent difference in calculated radon barrier thickness.

The UMTRA Project cover (shown in Figure 5–1) has a radon barrier thickness of 3.9 ft. The total cover system thickness is 8.2 ft from the top of the interim cover layer to the top of the rock mulch layer. Varying the long-term water content of the tailings does not have a significant impact on cover thickness. Increasing the interim cover thickness decreases the required radon barrier thickness by a 2:1 ratio (a 2-ft increase in interim cover thickness decreases the required radon barrier thickness by approximately 1 ft). Including the frost protection layer in the modeling decreases the required radon barrier thickness by 1.2 ft.

5.2.2 Alternative Cover

The alternative cover uses a monolithic soil layer placed at a density and moisture content similar to existing native soils conditions as the radon barrier and is modeled under conservative long-term soil moisture conditions. Because the monolithic layer has been modeled with the same density as the in-situ material, no frost protection layer is needed. Although the material will be placed as an engineered fill, the long-term conditions will reflect existing in-situ densities.

This monolithic soil layer will also be covered by a rock mulch designed to resist erosional forces caused by wind and surface water runoff under the Probable Maximum Flood (PMF) event, ensuring that the layer endures as an integral unit for the design life of the disposal cell. Because the rock mulch consists of native alluvium infilling all the inter-granular voids of the rock mulch, it is assumed to have essentially the same radon diffusion and attenuation characteristics of the monolithic layer and is modeled accordingly.

Several model runs were performed to assess model sensitivity to certain variables as described below.

- Model run Alt 1a uses mean input values for the alternative cover.
- Model runs Alt 1b and Alt 1c are sensitivity runs illustrating the effect of tailings moisture content on the calculated radon barrier thickness.
  - Model run Alt 1b is the same as Alt 1a but with the tailings moisture content set to 10 percent.
  - Model run Alt 1c is the same as Alt 1a but with the tailings moisture content set to 20 percent.

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

The alternative cover (shown in Figure 5–1) has a total cover system thickness of 9.8 ft from the top of the interim cover layer to the top of the rock mulch layer. This includes a rock mulch layer and an infiltration/biointrusion layer, each 0.5 ft thick. Varying the long-term moisture content of the tailings does not have a significant impact on cover thickness.

5.3 Summary and Conclusions

The disposal cell and radon barrier designs 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.

End of current text

6.0 Surface Water Hydrology and Erosion Protection

6.1 Hydrologic Description and Conceptual Design

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 some 25 mi south-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 3 to 4 ft in diameter provide drainage for flows west of Blaze Wash to pass under I-70. A pair of 6-ft-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-ft-diameter culvert allows discharge of Basin 3 to the south under I-70. Given small capacity of the 2- to 3-ft 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-ft 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 ft 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.

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 and 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 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 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 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.

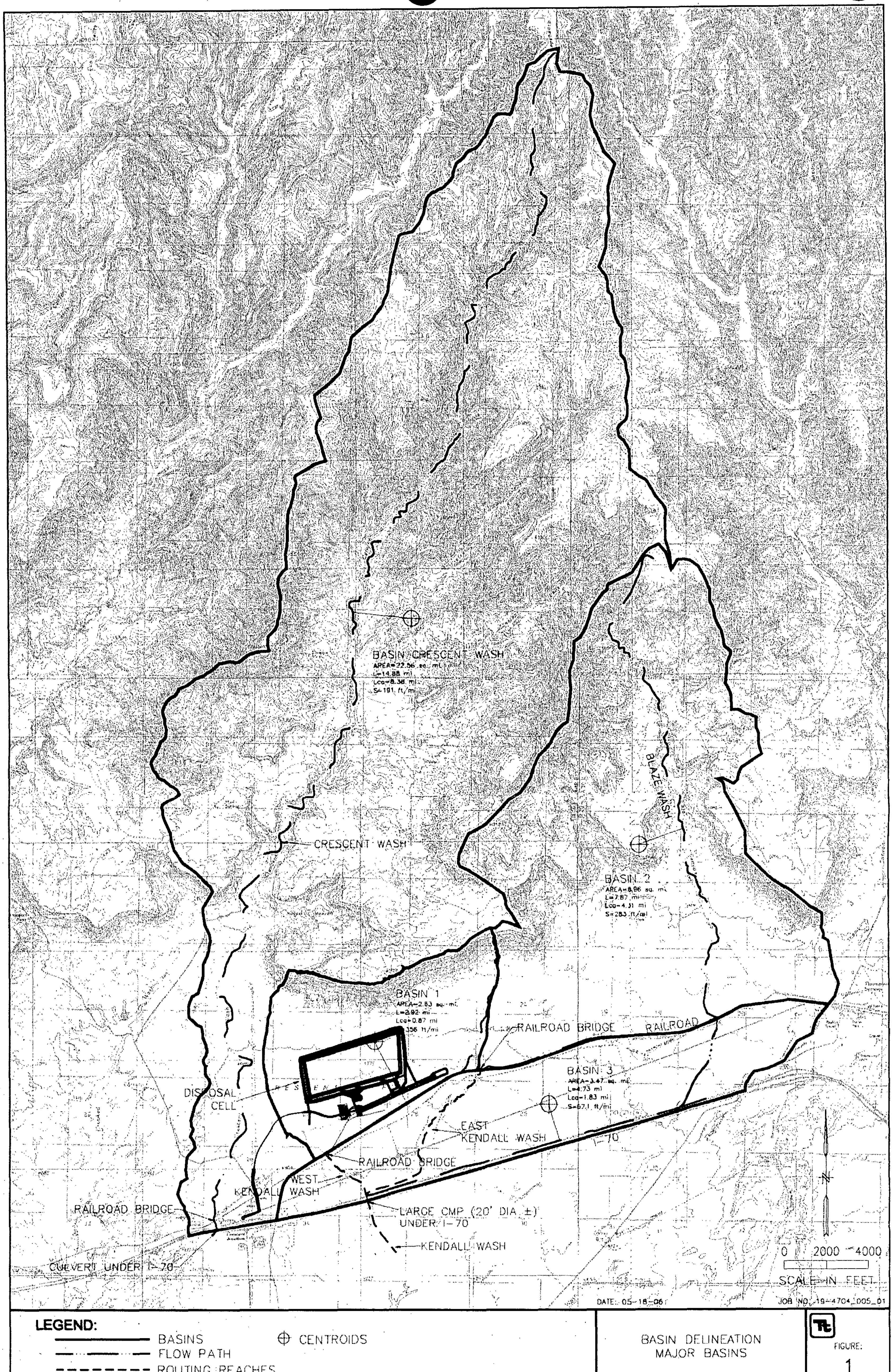

Figure 6–1. Basin Delineations in and Adjacent to the Crescent Junction Disposal Site

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- 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 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 southern California, Nevada, Utah, Arizona, western Colorado, and New Mexico. 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:

$$L_g = C(LL_{ca}/S^{0.5})$$

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 site (Table 3–3) (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 HEC-HMS (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	Peak Flow Rate (cubic feet per second [cfs])	
	(mi^2)	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 are 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 2 to 3 mi 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-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 2-ft 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 3. Because of differences in the level of accuracy of the 2-ft 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

6.4.1 Hydrologic Analysis of Disposal Cell

For the purpose of designing erosion protection along the north side of the disposal cell, Basin 1 is delineated into four subbasins based on locations of proposed swales, and bridges or culverts crossings. These subbasins (designated as A, B, D, and G) are shown on Figure 6–3 and Attachment 1, Appendix F. For the analyses, three ditches, or drainageways, were included on the north, south, and west sides of the disposal cell. These represent optional ditches for stormwater management during disposal cell construction.

The disposal cell will be protected from run-on with erosion protection along the lower portion of the north slope (Figure 6–3). These flows, which are ultimately tributaries to the West Branch of Kendall Wash, will be routed to the west past the disposal site, and then south and back into the West Branch of Kendall Wash.

Peak runoff flow rates and flood evaluations are determined at specific locations in the vicinity of the Crescent Junction Site for the PMP-local storm using the same procedures and methodologies presented in Section 6.2. Results are presented in Attachment 1, Appendix F and are summarized in Table 6–3.

Table 6–3. Peak Flow Rates, Major Storm Events

Design Point	Area (mi^2)	Peak Flow (cfs)
Basin 1 Drainage Facilities		PMP – Local
North Side of Cell	0.52	5,859
Northwest Corner of Cell (Design Point 4)	0.52	5,859
Southwest Corner of Cell (Design Point 5)	0.90	8,722
Existing Culvert (Design Point 3)	0.17	1,488

6.4.2 Top Slope and Side Slopes

To protect the top surface and side slopes of the disposal cell against erosion, the surfaces will be covered with rock mulch. The top surface protection will consist of a 6-inch layer of rock or rock mulch with a median particle size (D_{50}) of at least 2 inches. The west, north, and east side slopes will be protected with a 6-inch layer of rock or rock mulch with a minimum D_{50} of 2 to 3 inches.

The south slope, which receives runoff from the top slope, will require a 14-inch-thick layer of rock mulch with a minimum D_{50} of 7 inches. The rock protection placed on the south slope 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 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 3 to account for potential flow channelization. Conservative values were used for input parameters, including a specific gravity 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. 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 6–4. Complete analyses are provided in Attachment 1, Appendix H.

Table 6–4. Summary of Erosion Protection Materials

Location	Slope (percent)	Minimum D_{50} (inches)	Layer Thickness (inches)	Bedding Layer Thickness (inches)	Apron Width (ft)	Apron Embedment Depth (ft)
Top Surface	2	2	6	0	N/A	N/A
South Side Slope	20	7	14	6	N/A	N/A
West Side Slope	20	3	6	0	N/A	N/A
North Side Slope	20	2	6	0	N/A	N/A
East Side Slope	20	3	6	0	N/A	N/A
South Toe Apron	2	13	41	0	17	2.5
West Toe Apron	2	5	15	0	6	1.0
East Toe Apron	2	6	18	0	7	1.0
North Slope Bank	0.5–20	5–7	10–14	6	N/A	N/A

6.4.3 Toe of Slopes

To protect the toe along the south, west, and east sides of the disposal cell, a toe apron will be constructed at the base of the side slopes. The toe area at the base of the south side slope will be protected with 13-inch rock (D_{50} minimum). The toe areas at the base of the west and east slopes, which have shorter slope lengths and attributing flow area, will be protected with a minimum D_{50} of 5- and 6-inch rock, respectively. This rock apron serves to dissipate flow energy as flow transitions to native ground and provides protection against scour. A summary of the required riprap sizes for erosion protection of the disposal cell toe is provided in Table 6–4. Complete analyses are provided in Attachment 1, Appendix H.

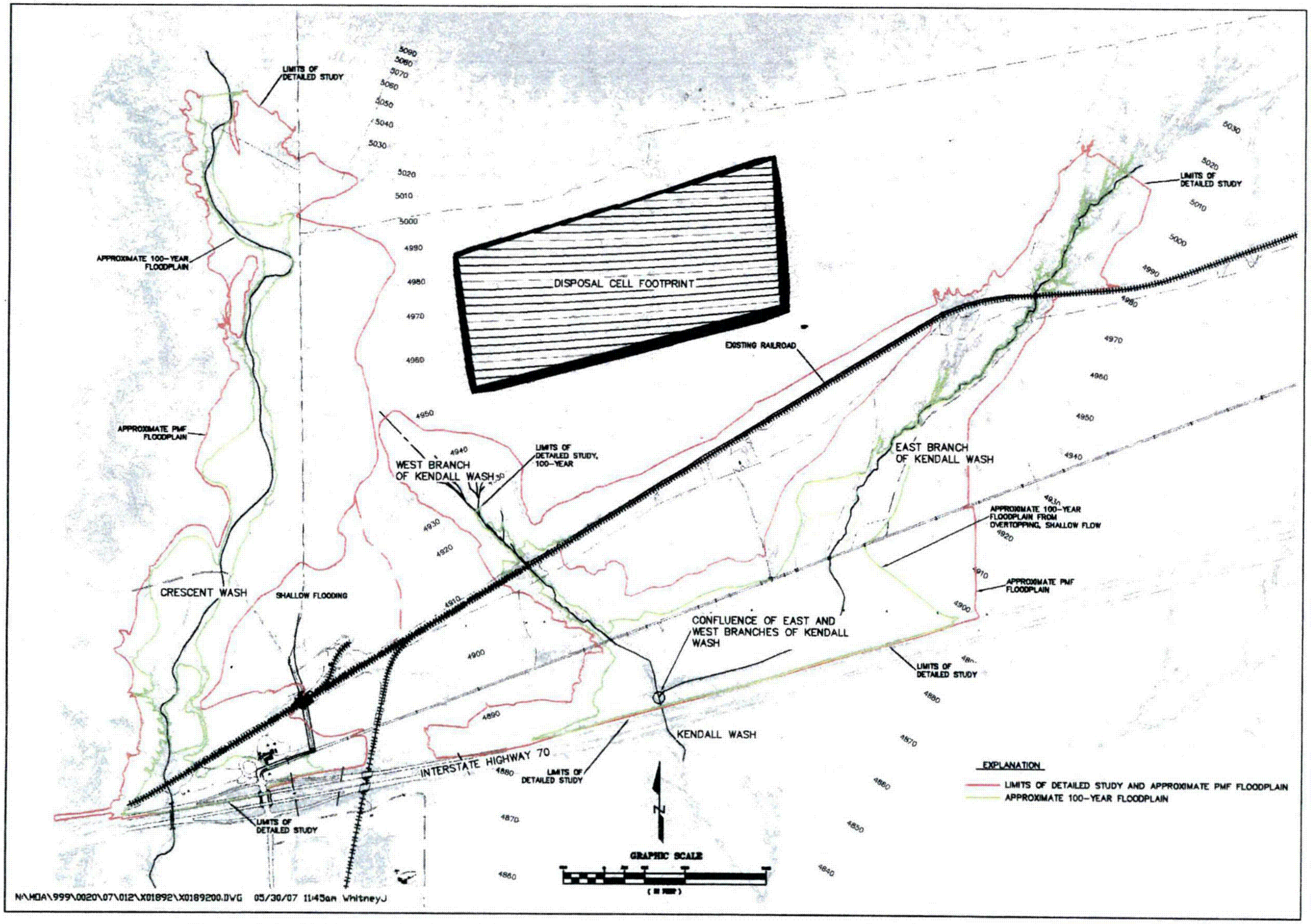

Figure 6–2. PMP and 100-Year Floodplain Delineations for the Crescent Junction Disposal Site

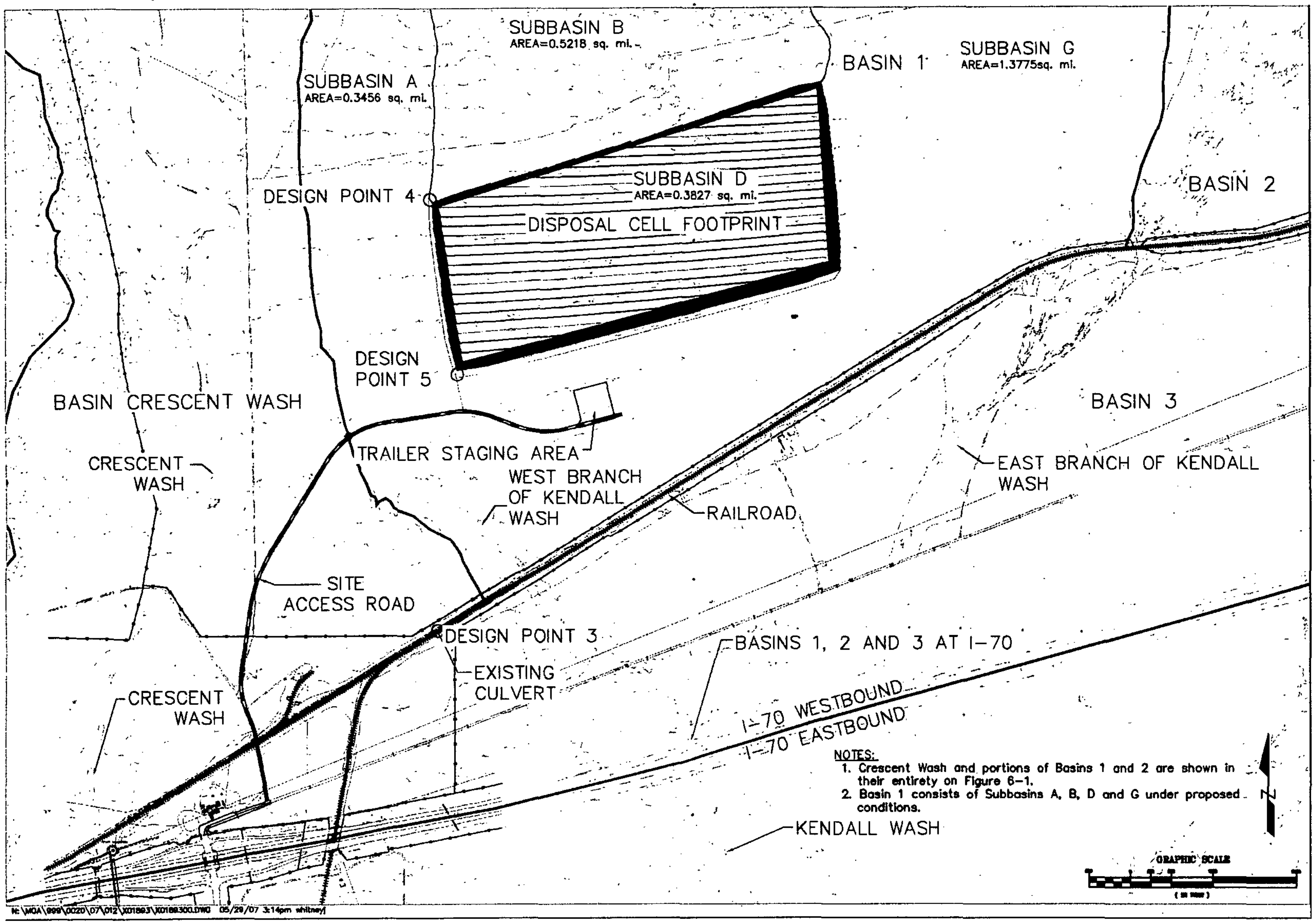

Figure 6–3. Crescent Junction Disposal Cell Site Drainage Plan

6.4.4 North Side of Cell

The north side of the disposal cell will experience runoff from upland precipitation (Basin 1 – Subbasin B, Figure 6–1). Erosion protection for the north side of the cell includes surface and self-launching riprap to: (1) prevent detrimental erosion from surface water flows from upland areas, (2) provide positive drainage for flows to be conveyed west around the north side of the disposal cell, and (3) prevent headward erosion at the channel outlet from impacting the disposal cell. The design hydraulic event is the PMP. Riprap size was designed based on the Safety Factor Method. The volume of self-launching riprap is adequate to armor the potential scour area past the maximum depth of scour, calculated using U.S. Department of Transportation (DOT) procedures (DOT 1983).

A channel will be constructed along the toe of the north side of the disposal cell for erosion protection placement, at a bed slope of 0.5 percent (Figure 6–4). This channel is expected to fill with sediment and erode during disposal cell operation.

The south slope of the diversion channel consists of channel riprap overlying the toe of the disposal cell (Figure 6–5). The riprap has been sized to provide erosion protection from the PMP. The channel riprap will extend up the north face of the disposal cell to a height equal to the calculated depth of flow under the PMP. Freeboard has not been included, because the design is for the PMP. In addition, sediments that have settled in the channel from smaller events are expected to flush out during large storm events.

The north slope of the channel consists of native soils at natural grade. In areas where grading is required to meet the 0.5 percent bed slope, the north slope of the channel will be excavated at a 20 percent slope until it meets natural grade. The north slope of the channel is not armored and is allowed to erode under large storm events. Scour beneath the toe of the disposal cell is prevented by the volume of self-launching riprap placed at the toe. The maximum estimated depth of scour is approximately 5.5 ft.

The channel design has been divided into two reaches: upper and lower. The upper reach consists of the first 2,000 ft of channel, and the lower reach is the remaining downstream portion. For the upper reach of the diversion channel, the required D_{50} of riprap for the slope protection and the buried rock wall is 5 inches. The riprap should extend a minimum of 8 ft above the channel bed. For the lower reach of the diversion channel, the required D_{50} of riprap is 7 inches and should extend a minimum of 10 ft above channel bed. The self-launching riprap should have a minimum D_{50} of 20 inches, and be placed with a minimum volume of 38 cubic ft per linear ft of channel.

The buried outlet apron will be constructed perpendicular to the channel outlet at the northwest corner of the cell to prevent headward erosion from flows at the outlet (Figure 6–6). Details of the diversion channel and outlet structure are in Attachment 1, Appendix G.

6.5 Rock Durability

Several sources of erosion protection rock have been evaluated and are potentially suitable for use at the site. Rock used for erosion protection will meet NRC durability requirements.

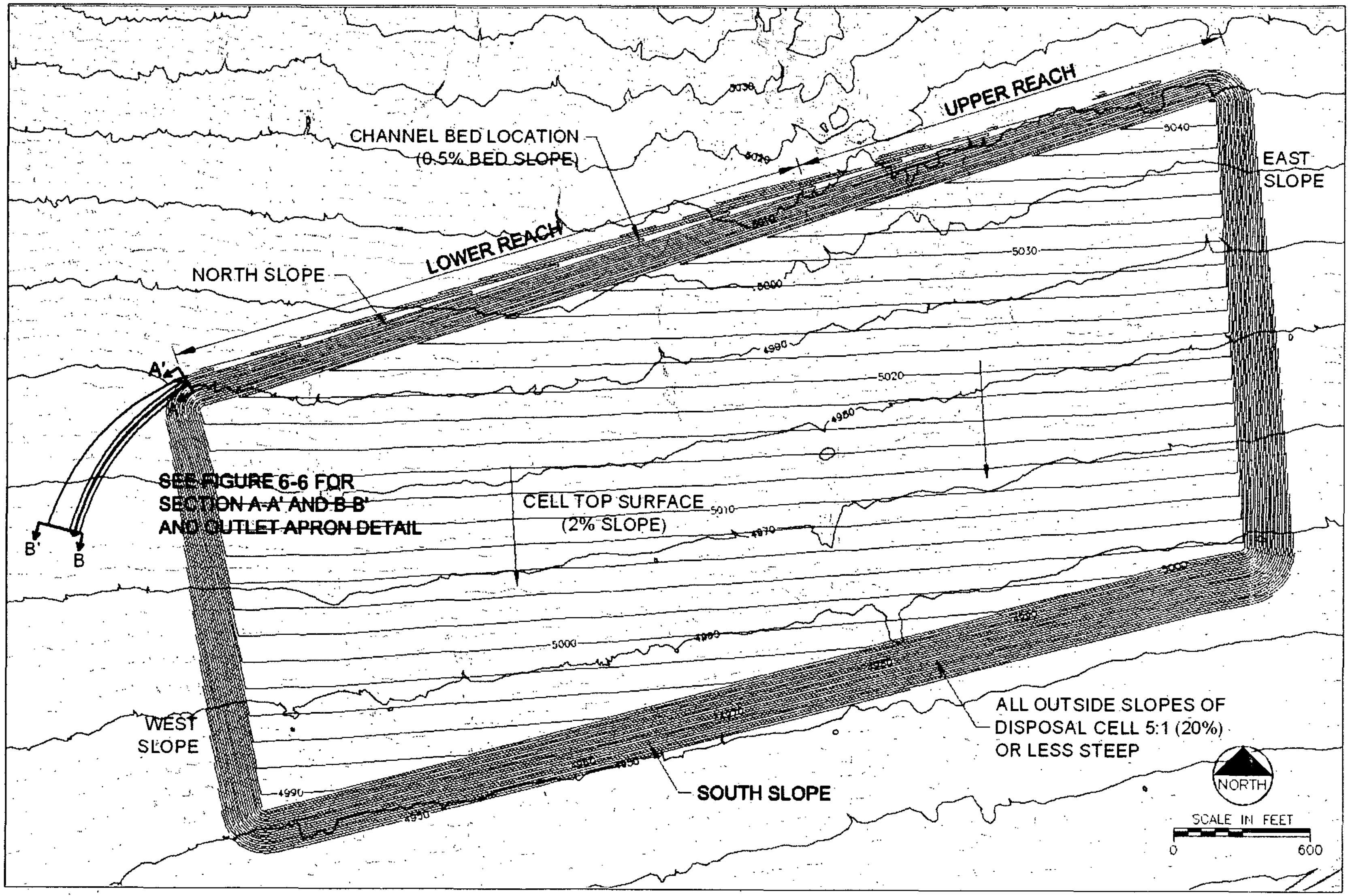

Figure 6–4. Disposal Cell Layout with Erosion Protection Features

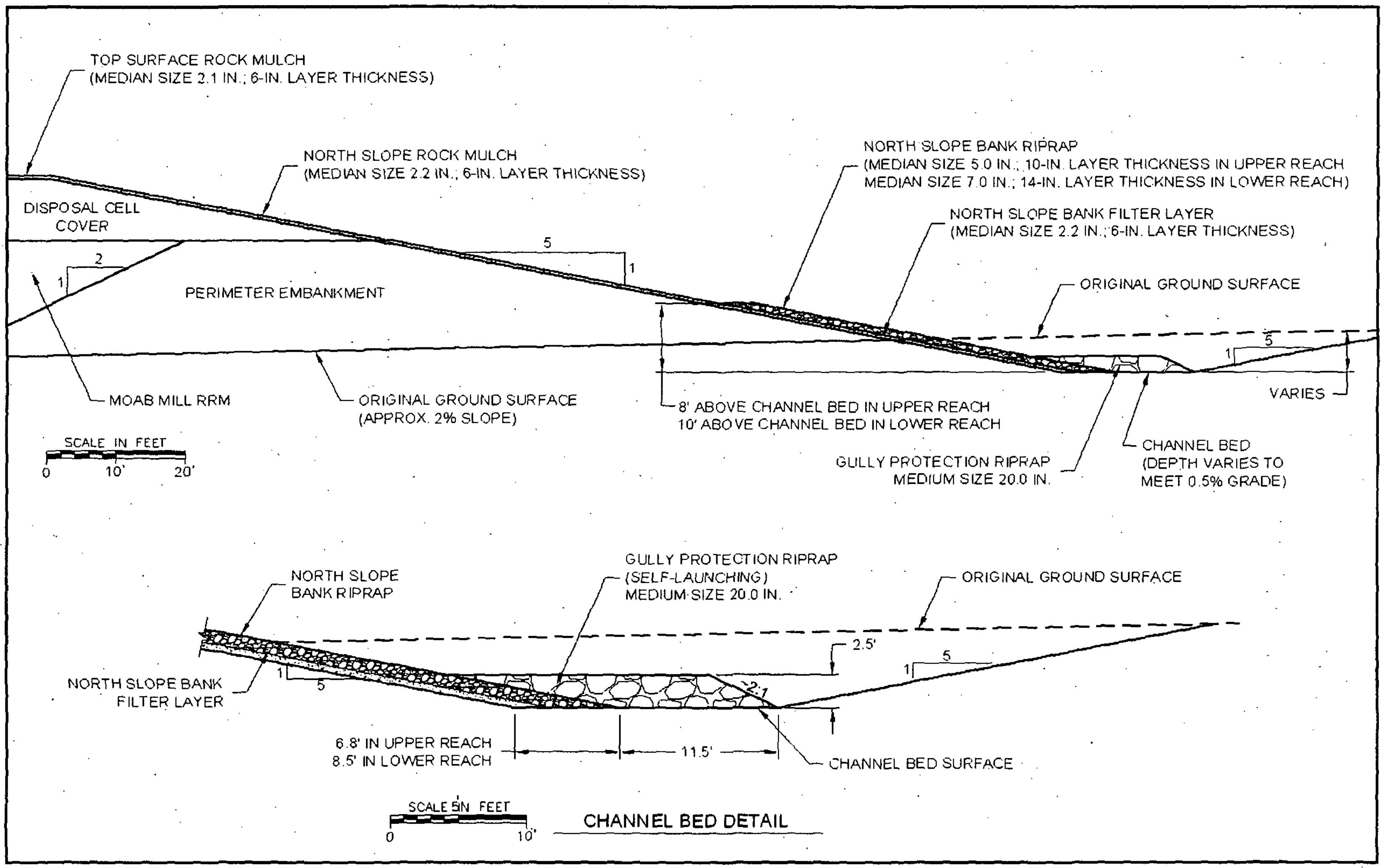

Figure 6–5. Typical Cross Section Through North Slope of Disposal Cell Showing Erosion Protection Material

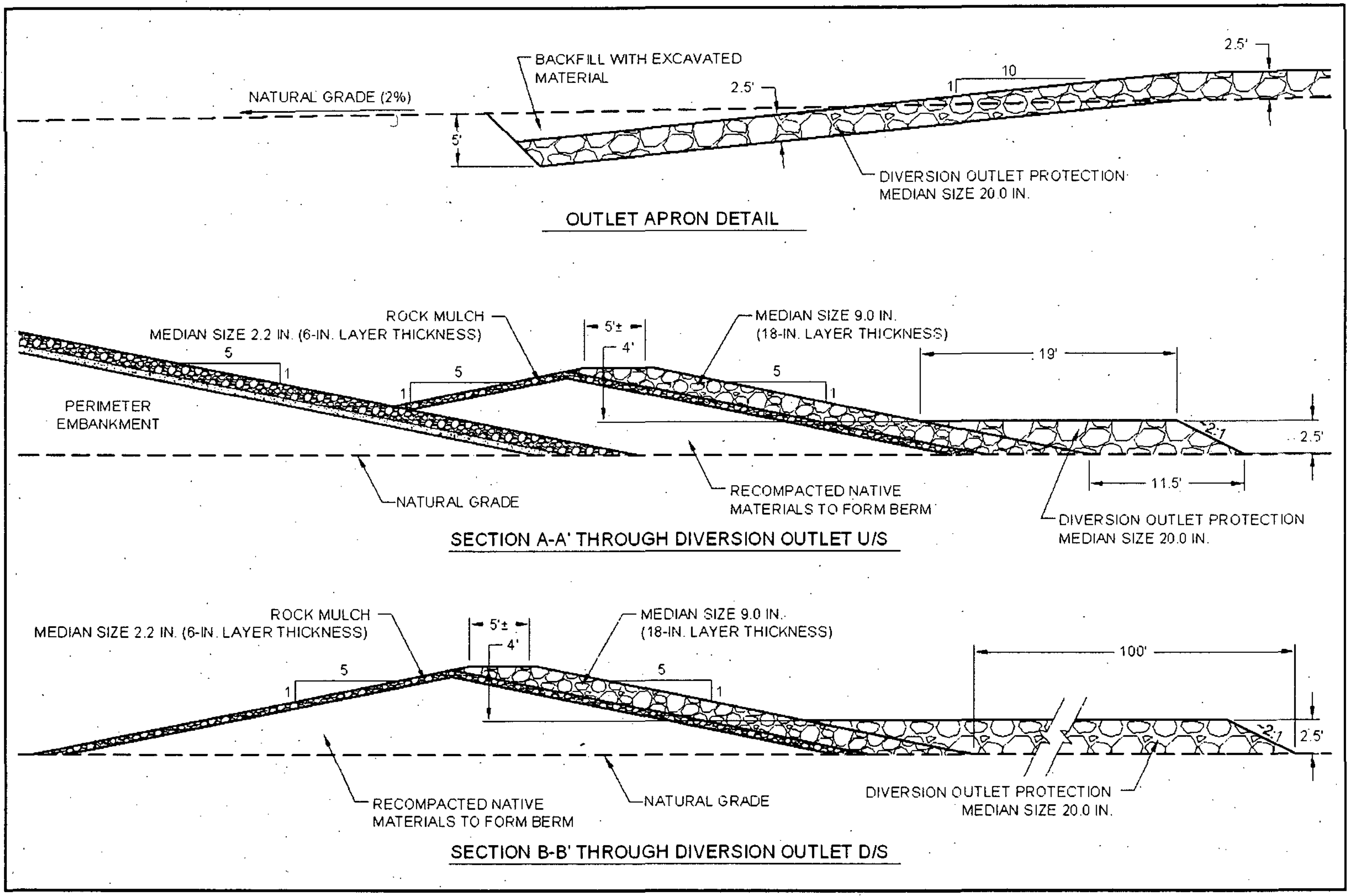

Figure 6–6. Buried Riprap Feature Plan and Cross Section

7.0 Conceptual Disposal Cell Design

This section summarizes the conceptual disposal cell design, based on information presented in Sections 4.0, 5.0, and 6.0 of the RAS Report, and Attachment 1 of the RAP. 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.
- Radon attenuation – evaluation of the disposal cell cover for acceptable radon emanation under long-term conditions. Two cover systems were evaluated: The typical UMTRA Project cover design and an alternative cover design.
- Surface water hydrology and erosion protection – acceptable performance was evaluated under long-term conditions (represented by using the PMP).

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

Assessment and incorporation of the above information has led to a conceptual design for the Crescent Junction disposal cell that will meet the regulatory requirements of 40 CFR 192 and will be protective of human health and the environment for the design life of the cell.

Figure 7–1 shows the proposed disposal cell footprint and existing and proposed site features. Typical cross sections through the disposal cell are shown in Figure 7–2 and Figure 7–3. The trapezoidal disposal cell will cover approximately 250 acres, and will be constructed partially below grade. The anticipated depth of excavation is 15 to 20 ft. The top surface of the disposal cell is designed to match the surrounding site slope (2 percent). The side slopes of the disposal cell are designed with maximum slopes of 5:1 (20 percent).

The current design volume of the cell, based on the calculations in Attachment 1, Appendix I, is for 12 million yd^3. This accounts for RRM from the tailings pile, subpile, 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 3.42 million yd^3 of colluvial material and 1.69 million yd^3 of weathered Mancos Shale. The embankments require 1.24 million yd^3 of fill, while the UMTRA Project checklist cover design requires 2.94 million yd^3, and the alternative cover requires 3.57 million yd^3 of fill. Accounting for 10 to 15 percent shrinkage of material upon compaction, there will be an excess quantity of material of approximately 0.2 million yd^3 if the UMTRA Project cover is built, and a deficit of material of approximately 0.4 million yd^3 if the alternative cover is built. Excess excavated material will be transported off-site for possible backfill at the Moab Site, used as interim cover, or added to the outside slopes of the cell.

The north side of the disposal cell, nearer to the Book Cliffs, intersects the existing slope at an angle to provide a 0.5 percent grade to the west (Figure 7–3). This reduces the velocity of runoff against the north toe of slope, while maintaining the existing drainage path to the West Branch of Kendall Wash. The west and east sides of the cell are canted inward slightly to provide sheet flow for side slope runoff away from the toe of the side slopes.

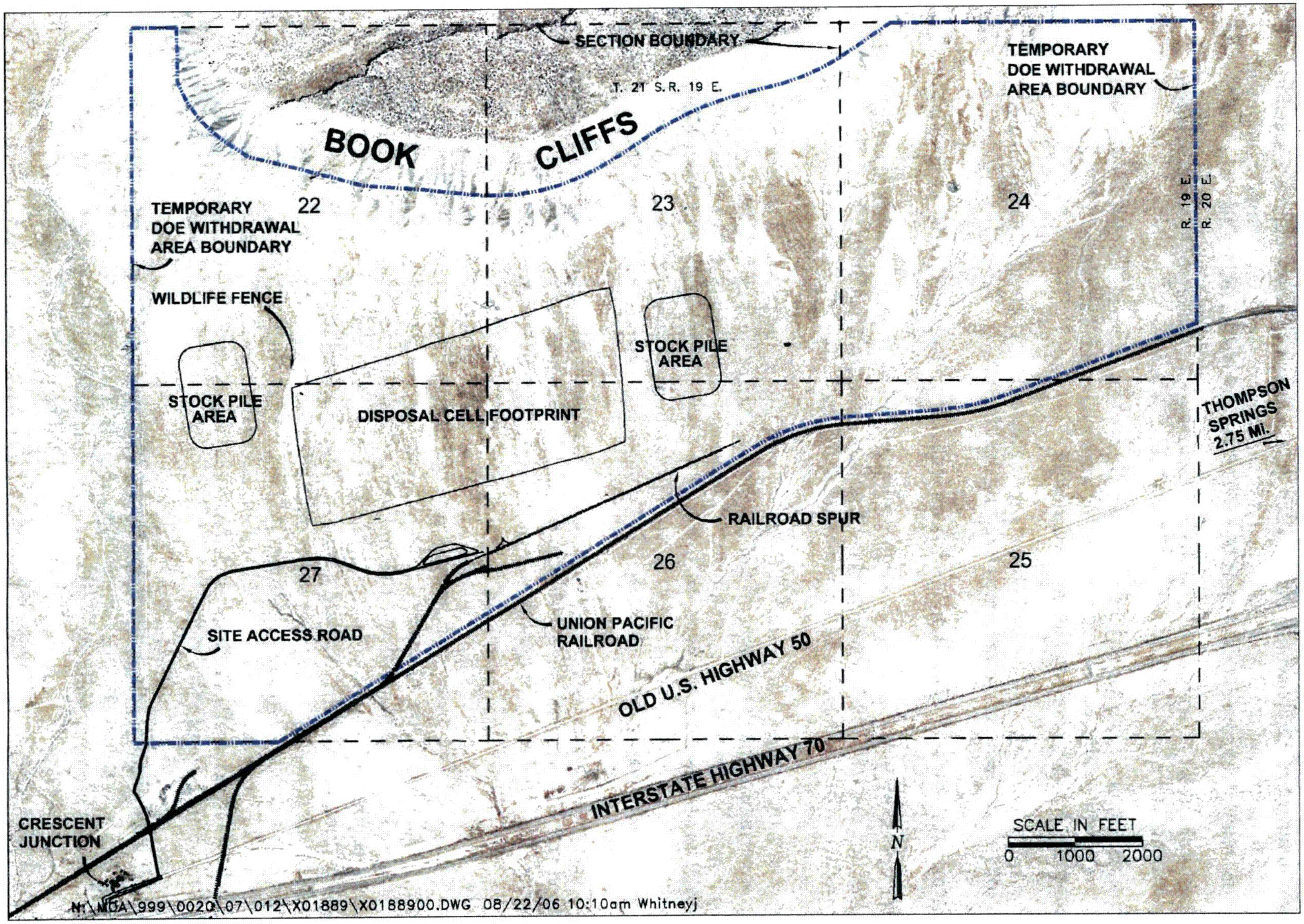

Figure 7–1. Crescent Junction Disposal Cell Footprint and Existing and Proposed Site Features

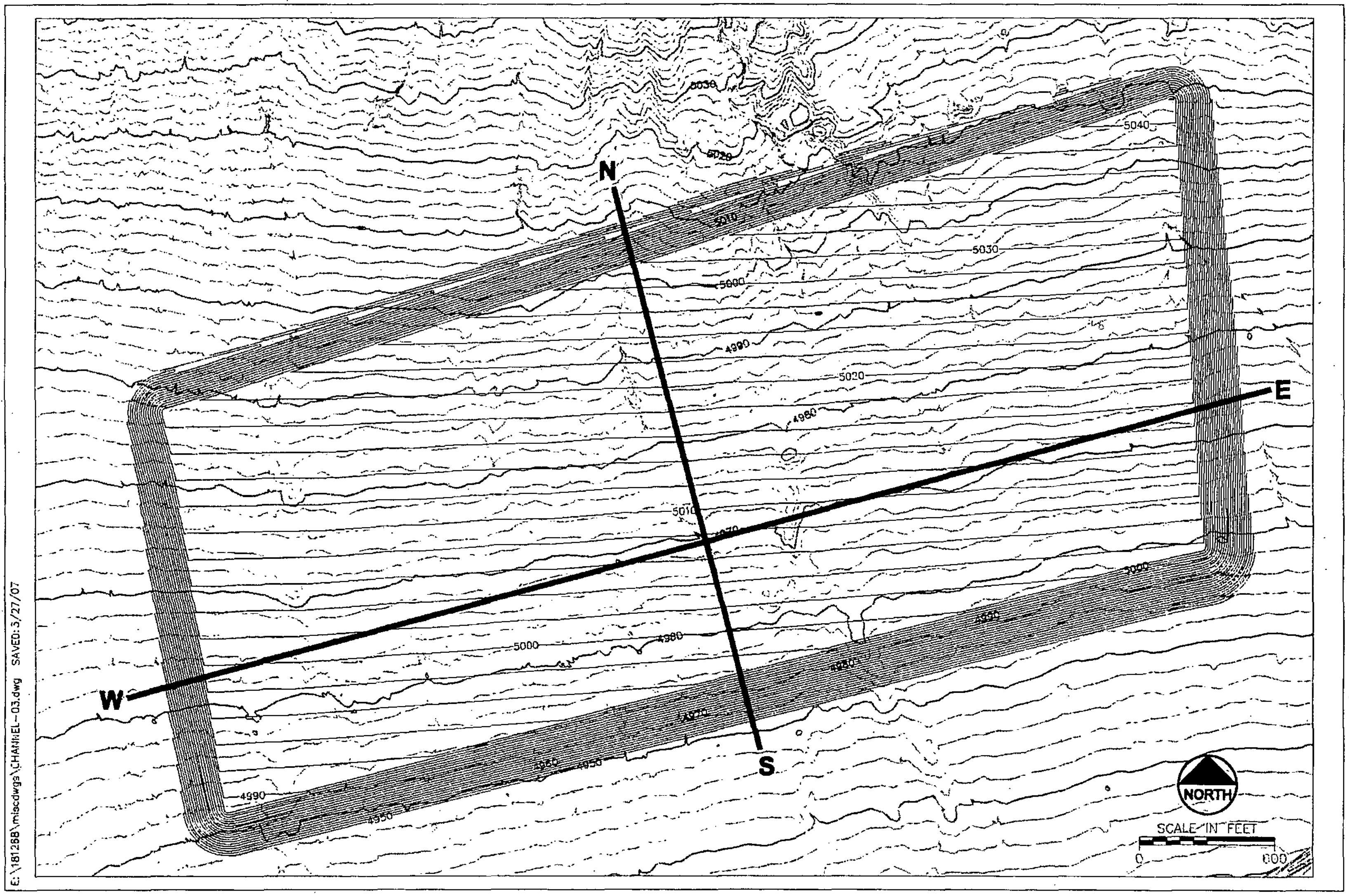

Figure 7–2. Disposal Cell Layout with Typical Cross-Section Locations

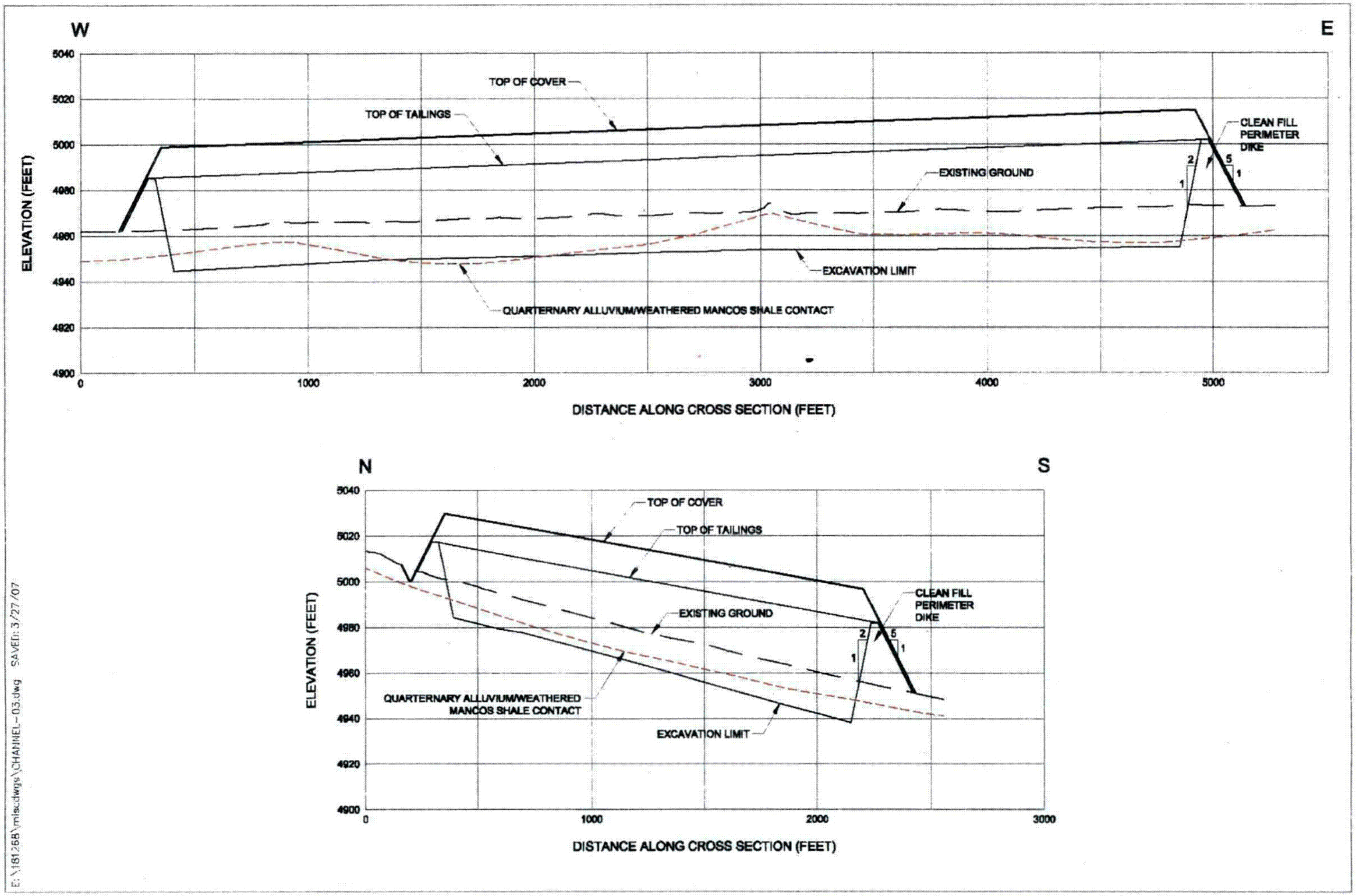

Figure 7–3. Typical Cross Sections for Crescent Junction Disposal Cell

The cell cover will include components to reduce radon emanation from the RRM, reduce infiltration of meteoric water into the RRM, and prevent biointrusion into the RRM. The disposal cell cover will be less permeable than the materials underlying the cell, which will prevent "bathtubbing" in the bottom of the cell. Clean fill dikes are incorporated into the design to minimize lateral water migration.

Aspects of biointrusion were initially analyzed, but no calculation set was developed. The thicker monolithic fill and biointrusion barrier for the alternative cover will provide protection against most plants and burrowing animals in the area. The biointrusion barrier over the radon barrier for the UMTRA Project cover should also provide adequate protection. 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.

A schematic depiction of the disposal cell in relationship to surrounding geologic and hydrogeologic features is shown on 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.

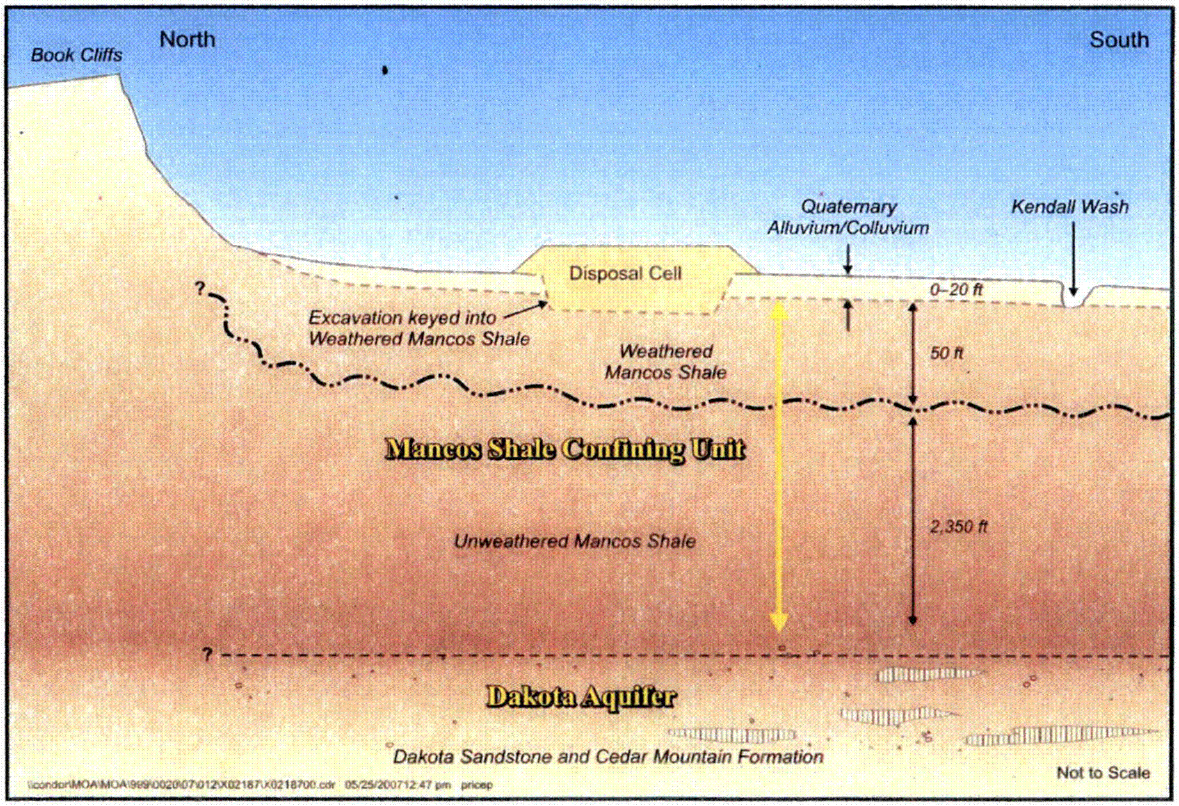

Figure 7–4. Schematic Diagram of Crescent Junction Disposal Cell and Surrounding Geologic and Hydrogeologic Features

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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 to 100 ft thick overlies the much thicker unweathered Mancos Shale. About 2,400 ft 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 1 to 2 mi of the site. Some local water users obtain water from springs located 7 mi 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 to 1,200 ft deep near Canyonlands Field (Grand County Airport), which is 15 mi south of the disposal site. The nearest major source of surface water is the Green River, 20 mi 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 preferred 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. A temporary standpipe to monitor transient drainage is discussed in Section 4.0 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. Attachment 1 discusses the disposal cell design in greater detail.

The alternative cover design should perform as well as the UMTRA Project cover from a ground water protection perspective.

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 Site 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 natural 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).

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 off-pile remediation, the vicinity property remediation, 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, slimes, and transitional material, 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 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 RRM has been estimated over the 439-acre area within the DOE property boundary. This volume includes the area 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 ft 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 below 5 pCi/g plus background and average subsurface (below 15 cm) radium-226 concentrations must be below 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 6 inches of fill. Some excavations are not backfilled and are subsequently remediated to 5 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 surface soil samples will be collected from a 100 m^2 area 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 procedure 4.7 in the Field Services Procedures Manual (STO 203).

A Global Positioning System/gamma scanning system may be used in lieu of soil sampling every 100-m^2 grid. Automated gamma measurements would be taken over 100 percent of all accessible areas and the data stored in a computer. Soil samples will be taken during the excavation control process to develop a correlation between the gamma readings and radium-226 concentrations. A minimum of 5 percent of the soil grids will be 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. A quality assurance plan will be submitted with the final RAP.

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.

By deferring ground water cleanup in the uppermost aquifer (alluvium) until the processing site can be adequately cleaned up and evaluated, human health and the environment will not be affected because: (1) the wells installed into contaminated ground water are for monitoring purposes only; (2) no wells are anticipated to be drilled to exploit alluvial ground water within this area in the near future; and (3) the high salinity of alluvial ground water precludes its use for most beneficial purposes.

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 in order 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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Appendix A

DOE Responses to NRC Comments

DOE Responses to NRC Comments

This Appendix to the Remedial Action Selection (RAS) Report contains the responses to U.S Nuclear Regulatory Commission (NRC) comments from meetings held in April and June 2006, to discuss the Draft Moab Remedial Action Plan (RAP). Comments, numbered from each meeting, are stated below along with a response. Comments from the April meeting were related to the topics of geology and seismology, while June meeting comments were related to ground water hydrology, water resources protection strategy, disposal cell design and engineering specifications, vicinity properties, and general interest.

The August 2006 version of the Draft RAP was submitted by the U.S. Department of Energy (DOE) to NRC for review. A Request for Additional Information was received from NRC in a letter dated February 9, 2007, based on a detailed technical review of the RAP and a site visit by NRC staff in December 2006.

NRC comments and DOE responses are presented in three sections to correspond to (1) comments from the April 2006 meeting, (2) comments from the June 2006 meeting, and (3) comments from the Request for Additional Information received in a February 2007 letter. All NRC issues have been addressed as detailed by DOE responses following each comment in the following text.

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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).

NRC Comments and DOE Responses
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.

NRC Comments and DOE Responses
February 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 7×10^{-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:

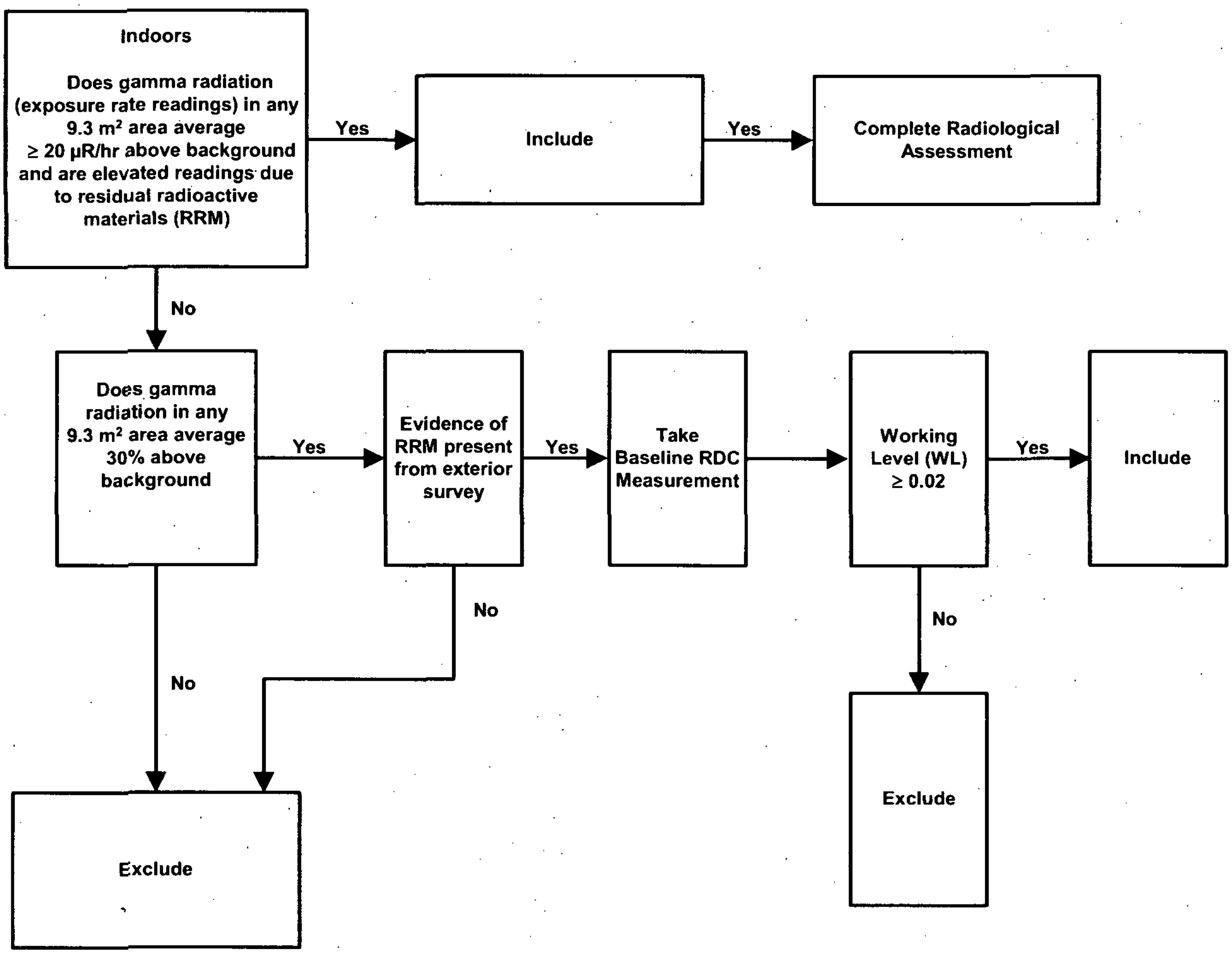
DOE is currently considering the use of supplemental standards on several areas on the millsite, Policaro vicinity property, and BLM properties surrounding the millsite. Examples of where DOE does not plan to remediate include: contamination under the highway asphalt; contamination around high-pressure 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:

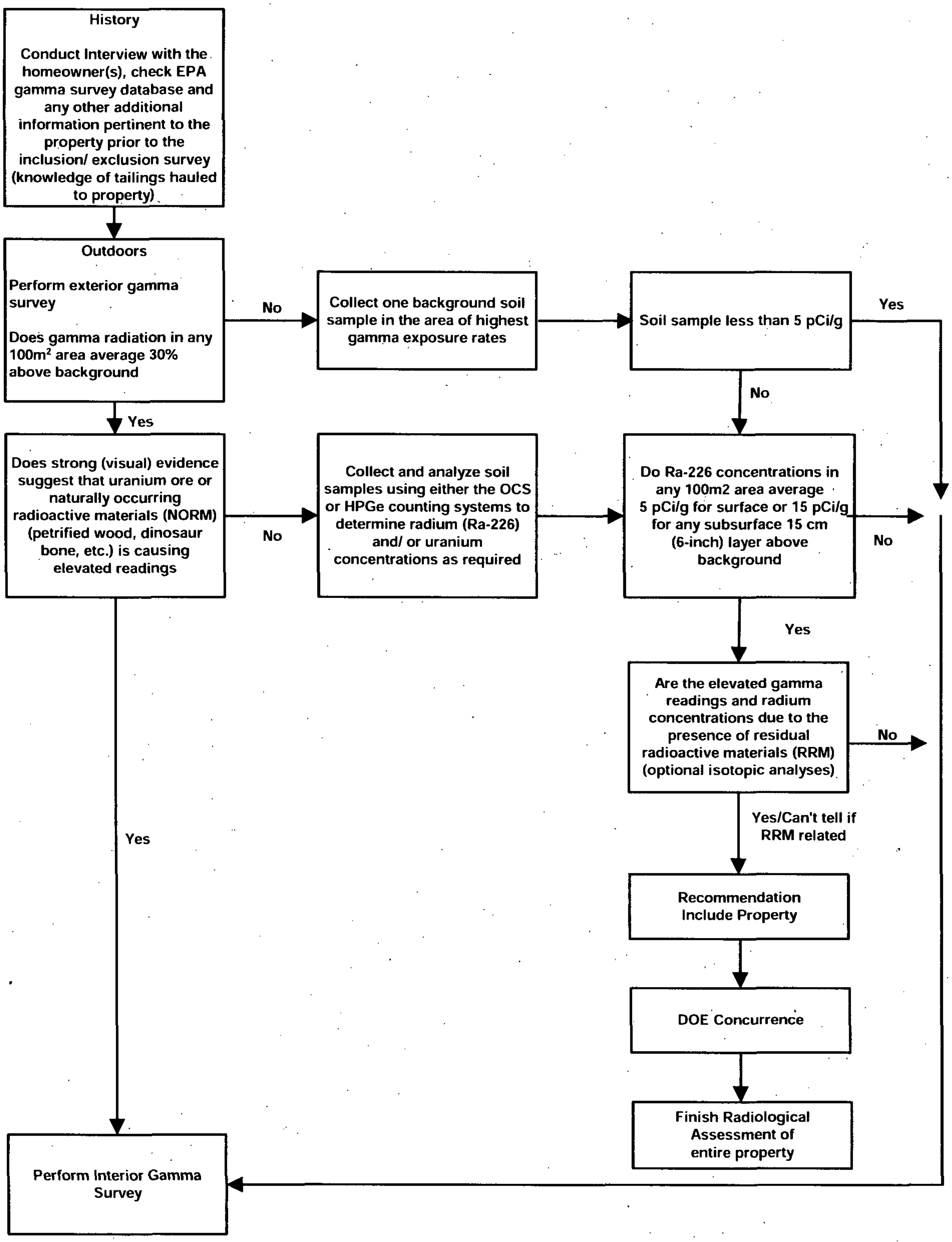
- Proposed use and justification of applying supplemental standards.
- Engineering alternatives studied, including costs to implement.
- Radiological levels.
- Health risks of leaving RRM behind.
- Potential for tailings movement or disturbance.
- Property owners' notification and input.

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



Appendix B

Technical Specifications Outline

TECHNICAL SPECIFICATIONS OUTLINE

1.0 SPECIAL PROVISIONS
- 1.1 Scope of Document
- 1.2 Definitions
- 1.3 Scope of Work
- 1.4 Applicable Regulations and Standards
- 1.5 Inspection and Quality Assurance
- 1.6 Construction Documentation
- 1.7 Design Modifications
- 1.8 Environmental Requirements
- 1.9 Water Management
- 1.10 Historical and Archeological Considerations
- 1.11 Health and Safety Requirements

2.0 SITE CONDITIONS
- 2.1 Site Location and Layout
- 2.2 Climate and Soil Conditions
- 2.3 Construction Water Supply
- 2.4 Utilities
- 2.5 Access and Security
- 2.6 Moab Mill Site Materials
  - 2.6.1 Mill Tailings
  - 2.6.2 Mill Debris
  - 2.6.3 Adjacent Soils
  - 2.6.4 Tailings Subsoils
- 2.7 Cell Construction Materials
  - 2.7.1 Alluvial Material
  - 2.7.2 Weathered Mancos Formation Material
  - 2.7.3 Plant Growth Material
  - 2.7.4 Erosion Protection Rock
  - 2.7.5 Bedding and Filter Material

3.0 WORK AREA PREPARATION
- 3.1 General
- 3.2 Clearing and Soil Salvage
- 3.3 Stormwater Management
- 3.4 Sediment Control
- 3.5 Dust Control
- 3.6 Facilities and Staging Areas
- 3.7 Disposal Cell Footprint
- 3.8 Stockpile Areas

4.0 DISPOSAL CELL CONSTRUCTION
- 4.1 General
- 4.2 Materials Description
  - 4.2.1 Embankment Structural Fill
  - 4.2.2 Inside Slope Fill
- 4.3 Work Description
  - 4.3.1 Cell Excavation
  - 4.3.2 Diversion Channel Excavation
  - 4.3.3 Inside Slope Fill Placement

4.3.4 Embankment Fill Placement
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4.4 Performance Standards and Testing
4.4.1 Disposal Cell Excavation Limits
4.4.2 Diversion Channel Excavation Limits
4.4.2 Embankment Structural Fill Testing
4.4.3 Inside Slope Fill Testing

5.0 DISPOSAL CELL OPERATION
5.1 General
5.2 Materials Description
5.2.1 Mill Tailings
5.2.2.1 Tailings Sands
5.2.2.2 Tailings Slimes
5.2.2.3 Intermediate Tailings
5.2.2 Mill Debris
5.2.3 Adjacent Soils
5.2.4 Tailings Subsoils
5.2.5 Interim Cover
5.3 Work Description
5.3.1 Tailings Placement
5.3.2 Mill Debris Placement
5.3.3 Soil Placement
5.3.4 Interim Cover Placement
5.4 Performance Standards and Testing
5.4.1 Tailings and Soil Testing
5.4.2 Interim Cover Testing
5.4.3 Grades and Slopes

6.0 DISPOSAL CELL COVER CONSTRUCTION
6.1 General
6.2 Materials Description
6.2.1 Radon Barrier
6.2.2 Infiltration Barrier
6.2.3 Frost Protection Layer
6.2.4 Top Surface Rock Mulch
6.2.5 Side Slope Rock Mulch
6.2.6 Side Slope Riprap
6.2.7 Side Slope Filter Layer
6.2.8 DiversionChannel Bank Riprap
6.2.9 Diversion Channel Outlet Riprap
6.3 Work Description
6.3.1 Radon Barrier Placement
6.3.2 Infiltration Barrier Placement
6.3.3 Frost Protection Layer Placement
6.3.4 Top Surface Rock Mulch Placement
6.3.5 Side Slope Rock Mulch Placement
6.3.6 Side Slope Riprap Placement
6.3.7 Side Slope Filter Layer Placement
6.3.8 Diversion Channel Bank Riprap Placement
6.3.9 Diversion Channel Outlet Riprap Placement

6.4 Performance Standard and Testing
- 6.4.1 Radon Barrier Testing
- 6.4.2 Infiltration Barrier Testing
- 6.4.3 Frost Protection Layer Testing
- 6.4.4 Rock Mulch Testing
- 6.4.5 Filter Layer Testing
- 6.4.6 Riprap Testing
- 6.4.7 Surface Slopes and Grades

7.0 DISPOSAL CELL REVEGETATION

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7.2 Materials Description
- 7.2.1 Soil Amendments
- 7.2.2 Seed Mix
- 7.2.3 Temporary Erosion Control Materials

7.3 Work Description
- 7.3.1 Soil Amendment Application
- 7.3.2 Growth Zone Preparation
- 7.3.3 Seed Application
- 7.3.4 Erosion Control Material Placement

7.4 Performance Standard and Testing
- 7.4.1 Vegetation Establishment Performance
- 7.4.2 Erosion Control
- 7.4.3 Weed Control

SUGGESTED LIST OF DRAWINGS

1. SITE LOCATION AND DISPOSAL CELL LAYOUT
2. CELL CONSTRUCTION SEQUENCE AND GRADING PLAN
3. COMPLETED DISPOSAL CELL LAYOUT
4. TYPICAL DISPOSAL CELL CROSS SECTIONS
5. TYPICAL DISPOSAL CELL DETAILS

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